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REVIEW ARTICLE

Safety of tongue base procedures for sleep apnoea in adults: A systematic review and metanalysis from the YO-IFOS study group

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KEYWORDS
Tongue base;
OSA;
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Lingual suspension;
SMILE

Abstract
Objective: Tongue base and hypopharynx are the major sites of obstruction in OSA patients with failed palatal surgery. In recent years, several minimally invasive procedures have been developed to address tongue base obstruction. However, the research focus has consistently been on the effectiveness of surgery in reducing obstructive sleep apnoea rather than on postoperative complications. In this systematic review and metanalysis we aim to review the complication rate of minimally invasive base of tongue procedures for OSAS in adults.
Data sources: PubMed (Medline), the Cochrane Library, EMBASE, Scopus, SciELO and Trip Database.
Review methods: Data sources were checked by three authors of the YO-IFOS sleep apnoea study group. Three authors extracted the data. Main outcome was expressed as the complication rate and 95% confidence interval for each surgical technique.

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Results: 20 studies (542 patients) met the inclusion criteria. The mean complication rate is 12.79%; 4.65% for minor complications, 6.42% if they are moderate, and 1.77% if severe. The most reported complication overall is infection, in 1.95% of cases, followed by transient swallowing disorder, occurring in 1.30% of the total sample.
Conclusion: The heterogeneity amongst the included studies prevents us from obtaining solid conclusions. The available evidence suggests that minimally invasive base of tongue procedures may present a wide spectrum of complication rates, ranging from 4.4% in tongue base radiofrequency to up to 42.42% in tongue base ablation.

PALABRAS CLAVE
Base de la lengua;
AOS;
Apnea;
Radiofrecuencia de la base de la lengua;
TORS;
Suspensión lingual;
SMILE

Seguridad de la cirugía de la base de la lengua para la apnea obstructiva del sueño en adultos. Revisión sistemática y metaanálisis del grupo de investigación YO-IFOS

Resumen
Objetivo: La base de la lengua y la hipofaringe son los principales sitios de obstrucción en pacientes con AOS persistente tras una faringoplastia. En los últimos años se han desarrollado numerosas técnicas de cirugía mínimamente invasiva con el objetivo de tratar la obstrucción en este nivel. Sin embargo, el foco de los investigadores se ha situado habitualmente en la efectividad de la técnica para reducir el número de eventos obstructivos, más que en sus complicaciones. En esta revisión sistemática y metaanálisis se evalúa la incidencia de complicaciones de procedimientos mínimamente invasivos para la base de la lengua en pacientes adultos con AOS.
Bases de datos: PubMed (Medline), Cochrane Library, EMBASE, Scopus, SciELO y Trip Database.
Método de revisión: Las bases de datos fueron evaluadas por 3 autores del grupo de investigación en apnea YO-IFOS. Tres autores extrajeron la información. Los resultados principales se expresaron como porcentaje de complicación e intervalo de confianza al 95% para cada técnica quirúrgica.
Resultados: Veinte estudios (542 pacientes) cumplieron los criterios de inclusión. La incidencia media de complicaciones fue del 12,79%; un 4,65% fueron menores, un 6,42% moderadas y un 1,77% severas. La complicación más habitual fue infección en el 1,95% de los casos, seguida por alteración transitoria de la deglución en un 1,30%.
Conclusión: La heterogeneidad de los artículos incluidos no permite obtener conclusiones firmes. La evidencia disponible muestra que la cirugía mínimamente invasiva de la base de la lengua presenta un intervalo amplio de complicaciones que varía entre el 4,4% en la radiofrecuencia de la base de la lengua y el 42,42% en la ablación de la base de la lengua.

Introduction

Obstructive sleep apnea syndrome (OSAS) is a growing health problem which affects 23.4% of women and 49.7% of men.[1] It increases the utilization of the health care services and overall mortality rates, mainly through increased incidence of cardiovascular disease, endocrine disorders and automobile accidents.

Surgical management of sleep disordered breathing (SDB) has undergone considerable evolution from individual procedures to the more accepted norm today, the multilevel approach, addressing several levels of obstruction in the same patient.[2]

In their extensive meta-analysis of 37 published reports on uvulopalatopharyngoplasty (UPPP), Sher et al. reported an overall success of UPPP for OSAS of 40.7%. However, in selected patients with retrolingual collapse the success rate for UPPP alone was as low as 5–10%.[3] This finding has been further confirmed by other authors who report untreated tongue base obstruction as the major cause of failure after the surgical treatment of OSAS.[4] In fact, studies based on somnoscopy and manometry have shown tongue base and hypopharynx to be the major sites of obstruction in patients with obstructive sleep apnea (OSA), possibly explaining the cause of failure in palatal surgery.[5]

The surgical treatment of retrolingual obstruction due to tongue base hypertrophy or collapse is still a problem for which a satisfactory long-lasting solution is difficult to find. In recent years, several procedures addressing tongue base obstruction have been described. Initial techniques were

thought to be excessively aggressive and were not widely accepted. Lately, given technological advancement, new minimally invasive procedures have gained in popularity, becoming commonplace in the day to day of clinical practice. The concept of minimally invasive surgery in too broad, as it is a general concept of surgery minimizing surgical incisions to reduce trauma to the body, reducing complications, postoperative pain, scarring and recovery time. However, despite this definition, some professionals may differ in which surgeries could be or not be considered as minimally invasive.

The most popular minimally invasive techniques are either performed with local anesthesia, or they claim to have a minimal morbidity and hospital stay. These are principally submucosal minimally invasive lingual excision (SMILE), tongue base ablation (TBA), tongue base radiofrequency (TBRF), lingual suspension (LS) and transoral robotic surgery (TORS).

However, despite the extensive number of reviews assessing their effect in controlling OSAS, the researcher's focus has consistently been on the effectiveness of surgery in reducing obstructive sleep apnea rather than on postoperative complications. Minimally invasive base of tongue procedures are consistently thought to be safe, however, some of their complications are severe, including hypoglossal nerve palsy, or damage to the lingual artery.

In this systematic review and metanalysis we aim to review the complication rate of minimally invasive base of tongue procedures for OSAS.

Methods

This review was performed in accordance with PRISMA (Preferred Reporting Items For Systematic Reviews And Meta-Analyses) guidelines, and a formal PROSPERO protocol was published according to the NHS International Prospective Register of Systematic Review (N° CRD42020213879) prior to conducting the review. Also, we followed the recommendations of the AMSTAR-2 guidelines.

Literature search. inclusion and exclusion criteria

The criteria for considering studies for the systematic review were based on the population, intervention, comparison, and outcome (PICOS) framework.

Participants: Adults over eighteen-year-old suffering from snoring and OSAS.

Intervention: isolated tongue base surgery, including lingual suspension, tongue base radiofrequency; SMILE, TORS and tongue base ablation.

Comparison: pre- and post-treatment data (case series of more than 5 patients or quasiexperimental studies), or treatment and no treatment cohorts (cohorts and clinical trials).

Outcomes: complication rate.

Types of studies: Clinical trials, case series of more than 5 participants, quasiexperimental studies, prospective and retrospective cohort studies published in peer-reviewed journals. We did not include case reports, thesis or meeting communications. There were no restrictions by date or publication type, and the last update of the search was performed in Jun 2020. We included studies published in English, Spanish, German, French, Italian and Portuguese.

Exclusion criteria: exclusion criteria consisted of associated procedures without subgroup analysis; syndromic patients; and language. When multiple articles reported the same subject cohort, only the study with the largest number of patients was included.

Search strategy

We followed the recommendations of the PRISMA statement systematic reviews and searched Pubmed (Medline), the Cochrane Library, EMBASE, Scopus, SciELO and Trip Database. We used a predefined search strategy [(''Tongue base reduction'' OR ''Submucosal minimally invasive lingual excision'' OR ''SMILE'' OR ''tongue base surgery'' OR ''lingual tonsillectomy'' OR ''glossectomy'' OR ''transoral robotic surgery'' OR ''TORS'' OR ''tongue coblation'' OR ''tongue base resection'' OR ''tongue resection'' OR ''Tongue reduction'' OR ''lingual excision'' OR ''lingual suspension'' OR ''tongue base suspension'' OR ''repose'' OR ''tongue suspension'' OR radiofrequency) AND (''sleep apn*'' OR ''SAHS'' OR ''OSA'' OR ''sleep-disordered breathing'' OR ''obstructive sleep apnea'')].

The abstracts of the papers retrieved were thoroughly reviewed by three authors, members of the sleep medicine research group of the Young Otolaryngologist International Federation of Otorhinolaryngological societies (YO-IFOS) (CCH, BBC, IRF), and those potentially fulfilling inclusion criteria were full-text read. Whenever differences in the judgement of eligibility arose, full texts were included for final assessment. We also manually reviewed the reference listings of all selected articles in order to identify works overlooked in the initial search.

Study extraction, categorization, and analysis

Three authors (CCH, BBC, IRF) analyzed the articles that met inclusion criteria twice. Variables assessed included sample size, age, body mass index; polysomnogram variables; use of steroids or antibiotics; number of sessions and amount of energy delivered (for TBRF), amount of resected tissue (for TORS, SMILE, tongue base ablation); follow-up period and main outcome. Main outcome was expressed as complication rate per treatment session. When there is a control sample it will be expressed as two different samples (participants and controls).

Complications were classified as mild, moderate and severe. This classification was decided through discussion between authors. We considered mild those complications easily managed with medical treatment, not requiring surgery, and not involving any nerve disability. Moderate were those complications requiring or potentially requiring minor intervention or those involving transient nerve disability.[1] Finally, severe complications were considered those instances which may compromise the patient's life, require a new surgical intervention or cause permanent disability.

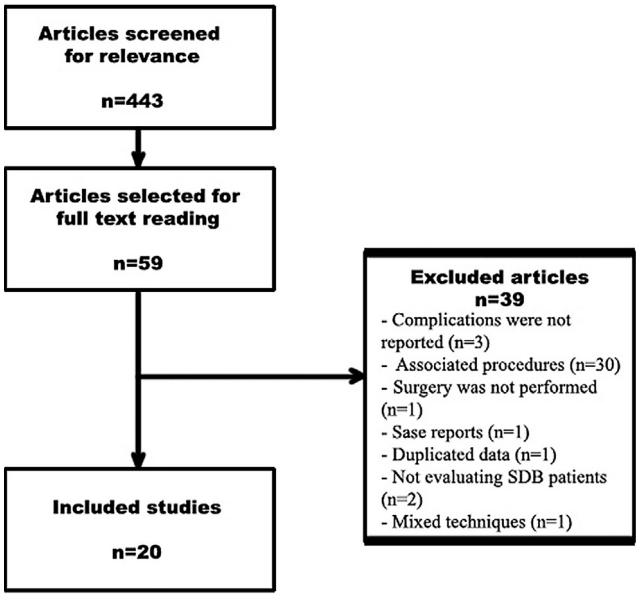

Figure 1 Flowchart.

Assessment of quality

We assessed the selected articles for both the level of evidence and quality. Level of evidence was classified according to the Oxford Centre for Evidence-Based Medicine Levels.

The risk of bias was assessed according to the Quality Assessment of case series studies checklist from the National Institute for Health and Clinical Excellence.

Statistical analysis

All statistical data were analyzed with STATA for Macintosh v. 15.1 (StataCorp ®). Significance was considered with a p value < 0.05.

Results

Search results

A flowchart of the search process appears in Fig. 1. The initial search retrieved 443 publications. After reading all titles and abstracts, 59 studies were selected for full text reading. A total of 20 studies (542 patients) met the inclusion criteria.[6–24]

Of the papers selected for full-text reading, 39 publications were excluded for the following reasons (references included in supplementary data 1): 3 papers in which complications were not reported, 30 had associated procedures without subgroup analysis; 1 surgery was not performed; 1 case reports; 1 duplicated data; 2 not evaluating SDB patients or not reported; and in 1 techniques were mixed and no sub-group analysis performed.

Results of the included studies

General results

General results are summarized in supplementary material 2. The mean sample size was 22.70. A total of seven articles performed TBRF (n = 188); seven TORS (n = 109), six lingual suspension suture (n = 172), one SMILE (n = 40) and another one tongue base ablation (n = 33).

Complication rate

The complication rate is summarized in Table 1. The mean complication rate for all studied techniques is 12.79%; 4.65% for minor complications, 6.42% if they are moderate and 1.77% if severe.

The technique with the highest complication rate was tongue base ablation with coblator yielding a 42.42% complication rate followed by TORS with a result of 35.78%. However, it must be highlighted that only one study for tongue base ablation was included.

Considering the severe complications rate, tongue base ablation is also the technique with the highest incidence, a 15.15%; followed again by TORS – 2.75%, being severe mouth floor edema, 0.84%, the most reported, followed by permanent taste disorder, 0.47%.

The most commonly reported complication overall is infection, in 1.95% of cases (CI 95% 1.13; 2.78), followed by transient swallowing disorder, occurring in 1.30% of the total sample. However, suture extrusion or fracture, which can only be reported when lingual suspension techniques are used, is the most frequently reported complication with an incidence of 9.30% (4.96; 13.64) when only this subgroup of articles are considered.

Study of cofactors

Age shows a weak non-significant correlation with the total complication rate (rho = 0.2922; p = 0.1761), while we found a non-significant negative correlation (rho = −0.2741; p = 0.2292) for AHI.

For TBRF, a Spearman correlation revealed a non-significant negative correlation between the number of sessions of TBRF and the total complication rate (rho = −0.6429, p = 0.1194), moderate complication (rho = −0.6847, p = 0.0897) and a weak positive non-significant correlation for mild (rho = 0.0741, p = 0.8745) and severe complication rates (rho = 0.5714, p = 0.1802).

Regarding the amount of energy delivered in TBRF, a Spearman correlation found a non-significant positive correlation between the energy per session and the complication rate (rho = 0.4643, p = 0.2939).

A total of five authors used unipolar energy, while two chose bipolar energy. They report a slightly higher total complication rate for bipolar energy (9.28%) than for unipolar (5.11%), but lower when considering the severe complication rate, it being 0% for bipolar and 1.72% for unipolar.

Regarding the use of steroids, only 8 studies reported whether they had been used (n = 6) or not (n = 2), with a mean complication rate of 15.04% and 2.09%respectively.

Regarding antibiotics, 10 studies reported their use, while in 3 studies they had not been prescribed. Mean complication rates were 17.78% and 35.87%, respectively.

Table 1 Complication rate of different tongue base surgeries.

Complications	TBRF	TORS	LS	SMILE	TBA	Total
Total	4.16 (2.70; 5.62)	36.70 (27.65; 45.75)	29.07 (22.28; 35.86)	10 (0.70; 19.30)	42.42 (25.56; 59.29)	12.83 (10.84; 14.83)
Minor complication (%, CI 95%)						
Minor Bleeding	0.00	7.34 (2.44; 12.24)	0.58 (−0.55; 1.72)	2.50 (−2.34; 7.34)	6.06 (−2.08; 14.20)	1.12 (0.49; 1.74)
Pain	0.00	3.67 (0.14; 7.20)	2.91 (0.40; 5.42)	0.00	0.00	0.84 (0.29; 1.38)
Infection	1.00 (0.26; 1.73)	0.92 (−0.87; 2.71)	6.98 (3.17; 10.78)	2.50 (−2.34; 7.34)	0.00	1.95 (1.13; 2.78)
Odynophagia	0.14 (−0.14; 0.42)	0.00	0.58 (−0.55; 1.72)	0.00	0.00	0.19 (−0.07; 0.44)
Foreign body feeling	0.00	0.00	0.58 (−0.55; 1.72)	0.00	0.00	0.09 (−0.09; 0.28)
Mucosal erosion/ulceration	0.71 (0.09; 1.34)	0.00	0.00	0.00	0.00	0.47 (0.06; 0.87)
Total	1.80 (0.83; 2.77)	11.93 (5.84; 18.01)	11.63 (6.84; 16.42)	5 (−1.75; 11.75)	6.06 (−2.08; 14.20)	4.65 (3.39; 5.91)
Moderate complication (%, CI 95%)						
Floor cyst	0.00	0.00	0.58 (−0.55; 1.72)	0.00	0.00	0.09 (−0.09; 0.28)
Granulated tissue	0.00	0.00	1.74 (−0.21; 3.70)	0.00	0.00	0.28 (−0.04; 0.59)
Transient speech disorder	0.00	0.00	0.58 (−0.55; 1.72)	0.00	0.00	0.09 (−0.09; 0.28)
Transient hypoglossal palsy	0.43 (−0.06; 0.91)	0.00	0.00	2.50 (−2.34; 7.34)	0.00	0.28 (−0.04; 0.59)
Transient neuralgia	0.14 (−0.14; 0.42)	0.00	0.00	0.00	0.00	0.09 (−0.09; 0.28)
Transient hypoesthesia	0.00	0.001	0.00	0.00	0.00	0.19 (−0.07; 0.44)
Hematoma	0.00	0.00	1.16 (−0.44; 2.76)	2.50 (−2.34; 7.34)	0.00	0.28 (−0.04; 0.59)
Transient taste nerve disorder	0.00	0.92 (−0.87; 2.71)	0.58 (−0.55; 1.72)	0.00	0.00	0.74 (0.23; 1.26)
Subcutaneous emphysema	0.00	0.92 (−0.87; 2.71)	0.00	0.00	0.00	0.09 (−0.09; 0.28)
Transient swallowing disorder	0.14 (−0.14; 0.42)	8.26 (3.09; 13.42)	0.58 (−0.55; 1.72)	0.00	9.09 (−0.72; 18.90)	1.30 (0.62; 1.98)
Suture extrusion/ Fracture	NA	NA	9.30 (4.96; 13.64)	NA	NA	NA
Transient tongue atrophy	0.00	0.00	0.58 (−0.55; 1.72)	0.00	0.00	0.09 (−0.09; 0.28)
Mild edema	0.29 (−0.11; 0.68)	4.59 (0.66; 8.51)	1.16 (−0.44; 2.76)	0.00	12.12 (0.99; 23.26)	1.30 (0.62; 1.98)
Total	0.97 (0.26; 1.69)	22.02 (14.24; 29.80)	16.86 (11.27; 22.46)	5 (−1.75; 11.75)	21.21 (7.26; 35.16)	6.42 (4.95; 7.88)
Severe complication (%, CI 95%)						
Tongue abscess/severe infection	0.43 (−0.06; 0.91)	0.00	0.00	0.00	0.00	0.28 (−0.04; 0.59)
Major bleeding	0.00	0.92 (−0.87; 2.71)	0.00	0.00	0.00	0.09 (−0.09; 0.28)
Severe mouth floor edema	0.86 (0.17; 1.54)	0.92 (−0.87; 2.71)	0.58 (−0.55; 1.72)	0.00	0.00	0.84 (0.29; 1.38)
Permanent speech disorder	0.00	0.00	0.58 (−0.55; 1.72)	0.00	0.00	0.00
Permanent taste disorder	0.00	6.42 (1.82; 11.02)	0.00	0.00	15.15 (2.92; 27.38)	0.47 (0.06; 0.87)
Oropharyngeal stenosis	0.00	0.92 (−0.87; 2.71)	1.74 (−0.21; 3.70)	0.00	0.00	0.09 (−0.09; 0.28)
Permanent hypoglossal nerve palsy	0.00	0.00	0.00	0.00	0.00	0.00
Total	1.39 (0.53; 2.24)	2.75 (−0.32; 5.82)	0.58 (−0.55; 1.72)	NA	15.15 (2.92; 27.38)	1.77 (0.98; 2.55)

Data presented as mean (95% confidence interval).
TBRF: tongue base radiofrequency. TORS: transoral robotic surgery. LS: lingual suspension. SMILE: submucosal minimally invasive lingual excision. TBA: tongue base ablation. NA: not applicable.

Follow-up

The mean follow-up period was 8.01 months, 7.66 adjusted by sample size, being 24 months the longest follow up, reported by Fibbi et al.,[6] and 1.5 months the minimum, reported by Den Herder et al and Welt et al.[7,24]

Level of evidence and quality of included studies

The level of evidence is summarized in supplementary material 2. The risk of bias in Table 2. There was one clinical trial (level 1b), by Babademez et al., comparing TORS and tongue ablation with coblator.[13] There were 3 prospective cohort studies, one by Woodson et al. (Level 2b), comparing TBRF and CPAP[11]; another one by Karaman et al., comparing TORS with CO_2 laser fiber and electrocautery[15]; and the last by Hou et al. (level 4), comparing SMILE, both via a dorsal and ventral approach.[23] There were 2 retrospective cohort studies (Level 4) by Fibbi et al. comparing TBRF and LS,[6] and Huntley et al comparing TORS with hypoglossal nerve stimulation.[14] Finally, there were 9 quasiexperimental studies (level 4)[8] and 3 case series (level 4).

Discussion

Despite some authors having previously studied the complication rates of some base of tongue procedures,[7,25,26] this is the first systematic review to specifically assess the complication rate of tongue base surgery as a standalone procedure for sleep disorder breathing. The data herein reported should be managed carefully, as it is highly biased by the ability of the surgeon, but also by the condition being treated, as OSA is related with comorbidities such as high blood pressure, obesity, or diabetes, which are, in turn, related with an increased surgical complication rate.

There is a paucity of studies specifically assessing the outcomes of independent tongue base surgery without any other concomitant procedure. This was expected, as available evidence suggests that tongue base surgery as an isolated treatment is rarely indicated. However, from an evidence and quality perspective, in order to calculate the complication rate, only this type of article can be included as multilevel surgery might introduce a bias in this analysis.

In this review we found a relatively high complication rate, a 12.79%, it being considerable higher for tongue base ablation (42.42%) and TORS (35.78%). When only severe complications are considered the complication rate is 1.77%, 15.15% for TBA and 2.75% for TORS.

Comparing our results with previous reports, Meccariello et al. reported a 21.3% complication rate for TORS[27] in multilevel surgery, while we found 36.70%. In regards to TBRF, Kezirian et al. reported a 3.45% of total complication rate per session and a 2.7% moderate and major complication rate.[26] This in in line with our results given that we found a 4.14% complication rate per session for TBRF.

Differences in surgical techniques

In spite of the fact that we have individualized results to each surgical technique, the use of a specific type of technology should not be mistaken for a technique in itself. As highlighted by Vicini et al., the complication rate is dependent on the specific procedure and not on the use of a certain technique.[18] For example, TORS may be used for different surgeries such as lingual tonsillectomy, as well as posterior midline glossectomy. Similarly, coblation may be used for SMILE, lingual tonsillectomy, or midline posterior glossectomy. Therefore, the final results should be weighted not only by the technology used, but also by the followed technique itself.

It is not standardized the number and energy settings delivered in each session for TBRF. The final results differ with the use of higher energy levels, and the energy used can be either mono or bipolar. Bipolar thermo-technology, as compared to monopolar, seems to reduce morbidity, such as secondary thermal damage, because less energy needs to be applied and treatment duration is reduced to several seconds per lesion. Furthermore, it has been described from a cervical,[8] ventral,[9] or dorsal approach.

For TORS, neither the amount and extension of the resection (posterior midline glossectomy, tongue base reduction, or only tongue tonsil removal) nor the equipment employed (laser, bipolar, ultrasonic scalpel) are standardized. In fact, Karaman et al. found a lower complication rate and surgical time with the use of CO_2 laser compared to electrocautery in TORS.[15]

Regarding LS, the approach was initially described as intraoral, becoming cervical in the latest reports, which has been described as having a lower complication rate. There is also a difference between using a mandible screw or not. Most techniques do not allow for the adjustment of the suture, with the exception of Woodson T., who used the Advance system.[11]

The SMILE has been described either through a dorsal or ventral approach. Hou et al., found the ventral approach to be the safest technique at the time, as there were no differences between the polysomnogram variables.[23]

Complications

Lesion of the lingual artery: this is probably one of the most dangerous complications in base of tongue surgery. Its anatomy has been widely studied,[18] however, lesions in the lingual artery have been reported by some of the included authors, with one case requiring ligation of the artery through a cervical approach. Cammarotto et al. recommend the use of a sonogram in order to identify the lingual artery when performing submucosal resection.[28] Although this technique has been widely reported, only one of the authors selected in this review used it.[8] With these safety measures they had no cases of bleeding but there was one instance of transient hypoglossal nerve palsy recorded. Furthermore, despite not being reported in any of the included studies, a case of pseudoaneurysm of the lingual artery after TBRF has also been described.[29]

Edema: In the first reports of TORS and TBRF, authors performed safety tracheostomies. However, this is not a common practice any longer when performing tongue base surgery as airway compromise was not a common complication. However, in our review, we found 0.76% of severe floor edema, a 0.92% in TORS and 0.86% in TBRF. A total of 4 authors detailed this complication,[6,10,11,15] but none of them encountered patients requiring emergent tracheostomy.

Table 2 Assessment of the risk of bias.

	1) Was the case series collected in more than one center?	2) Is the hypothesis/aim/objective of the study clearly described?	3) Are the inclusion and exclusion criteria clearly reported?	4) Is there a clear definition of the outcomes reported?	5) Were data collected prospectively?	6) Is there an explicit statement regarding whether patients were recruited consecutively?	7) Are the main findings of the study clearly described?	8) Are outcomes stratified?
Fibbi A. et al. (2009)	No	Yes	Yes	Yes	No	No	Yes	Yes
Welt S et al. (2007)	No	Yes	No	Yes	Yes	Yes	Yes	Yes
Den Herder C et al. (2006)	Unclear	Yes	No	Yes	Yes	Yes	Yes	Yes
Blumen MB et al. (2006)	No	No	Yes	Yes	Yes	Yes	Yes	No
Riley RW et al. (2003)	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Stuck BA et al. (2002)	No	Yes	Yes	Yes	Yes	No	Yes	No
Woodson BT et al. (2001)	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Powell NB et al. (1999)	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Babademez MA et al. (2019)	Unclear	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Huntley C et al. (2019)	No	Yes	No	Yes	No	Yes	Yes	Yes
Karaman M et al. (2017)	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Arora A et al. (2015)	No	Yes	Yes	Yes	Yes	No	Yes	No
Muderris T et al. (2014)	No	Yes	No	Yes	No	No	Yes	No
Vicini C et al. (2012)	No	Yes	No	Yes	No	No	Yes	No
Turhan M et al. (2015)	No	Yes	Yes	Yes	Yes	No	Yes	Yes
Woodson BT et al. (2010)	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	No
Kühnel TS et al. (2005)	No	Yes	No	Yes	Yes	No	Yes	No
Woodson BT et al. (2001)	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
De Rowe A et al. (2000)	Yes	Yes	Yes	Yes	No	No	Yes	No
Hou T et al. (2012)	No	Yes	Yes	Yes	Yes	Unclear	Yes	Yes

Hypoglossal nerve palsy: while hypoglossal nerve palsy is a constant fear in tongue base surgery, in this review none of the selected authors reported permanent paralysis and there was only 0.38% reported transient hypoglossal nerve palsy. It is interesting to note that authors who came across this complication were those who had performed blind techniques such as SMILE (2.50%) and TBRF (0.43%).

Infection: tongue abscess was only reported by authors performing TBRF (0.43%). However, and although not included in this review, this complication also arose with other techniques, such as base of tongue suspension suture after two years of follow-up.[30] Blumen et al. proposed a TBRF through a transcervical approach to avoid introducing oral bacteria into the lesion.[8] They did not find any infection in their samples. Osteomyelitis has not been reported in this review, but it has been described as a complication of lingual suspension sutures.[31]

Scarring: Muderris et al. reported a case of oropharyngeal stenosis due to scarring tissue among 6 TORS patients.[17] None of the other selected studies encountered this complication, which might be related to the fact that we only included papers in which tongue base surgery was performed as sole surgery, without pharyngeal surgery, as excessive damage to the adjacent mucosa has been proposed as a major risk factor for this complication.[32]

Confounding factors

Despite the fact that in this review we have tried to control the presence of concomitant surgeries, a major confounding factor, several other factors might impair our capacity to combine and compare results between papers.

The risks inherent to each procedure are related to the experience and expertise of each individual surgeon. Stuck et al. highlight that their postoperative complications were more frequent the year after the inauguration of the RFTB ablation, and it gradually fell in the following years.[33] This suggests that this technique, like the majority of surgical procedures, is dependent on the surgeon's experience, a variable which is difficult to capture in a review.

Stuck et al. reported that since postoperative antibiotic prophylaxis for TBRF has been in use, no base of tongue abscesses have occurred after 425 cases of treatment.[34] In this review we found a lower complication rate for authors using prophylactic antibiotics (17.78, vs 35.87%), which supports Stuck et al.'s hypothesis.

Pazos and Mair (not included as they mixed techniques) reported a significantly higher complication rate for TBRF(40%).[35] Stuck et al. suggested that this may be attributed to their routine use of corticosteroids for 5 days, which might have facilitated bacterial infection.[33] In this review we have also found a higher complication rate for authors using prophylactic steroids (15.04, vs 2.09%), which substantiates Stuck et al.'s aforementioned premise.

A total of nine authors used local anesthesia, lidocaine in most cases, but two of them employed bupivacaine,[9,12] which has been linked to myotoxicity.[36]

Regarding the use of other drugs, Vicini et al. used Floseal® after TORS.[37] and Hou et al. omeprazole after SMILE.[23]

The follow up period is different among selected authors. This could alter complication rates. For example, Kühnel et al. experienced an infection in the suture after 12 months of lingual suspension.[21] With regard to the base of tongue suspension suture none of the selected authors reported tongue abscess, however, instances of it have been noted, even after two years of follow-up.[30]

The technical aspects of the surgery might also alter the comparability of the samples, as some complications might be related to the technology used instead of the surgery itself. Woodson et al. reported 13/42 cases of suture fracture after LS,[20] which is notably superior to the rest of LS series.

Body mass index (BMI) has been found to influence outcomes after SAHS surgery.[38] Also, mean BMI varies among selected papers from 14.8 to 31, which might introduce a confounding factor. Note that there are no morbid obese patients as surgery is not usually performed in those patients.

Finally, the aggressivity of the surgery may affect the final results but also the complication rate. Steward et al. found that a higher total tongue base energy dose in TBRF ($10{,}700 \pm 600$ J instead of 3700 ± 1900 J) produced significantly greater RDI improvements. However, it might also increase the complication rate. Here we found different evidence, as Riley et al did not detect variations when using different amounts of energy,[9] but, in their study, Stuck et al. concluded that the increased number of adverse events in their series may have been due to the increasing amount of energy applied per treatment session.[10]

In other surgeries, like TORS or SMILE, the amount of resected tissue might influence the final results. However, this variable has been poorly described by authors. Karaman et al. reported that, in their experience, the volume of excised tissue is not relevant if it is less than 7 ml; and excising more than 50 ml may cause complications.[15] Interestingly, Friedman et al obtained a low correlation between the amount of resected tissue and AHI improvement. However, it was higher for ESS.[39] Muderris et al. established that there was a significant correlation between the removed mass from lingual tonsillar tissue and the degree of improvement in the functional data.[17]

The preoperative characteristics of patients are not comparable. Vicini et al. suggested that tongue base radiofrequency should be reserved for mild cases, while TORS for severe. There is no clear description of the degree of tongue base obstruction to compare results between techniques. However, our review found a wide range in the severity of the included patients regarding polysomnogram data, which might influence the outcomes and impair our ability to compare studies.

Finally, there might exist a reporting bias, as some complications may have been missed altogether. Severe complications would be less prone, as they are easily reported by patients and explored by surgeons. However, mild complications may have been overlooked or even not considered a complication by some authors. For example, den Herder et al. reported transient tongue deviation as a complication,[7] while Woodson et al. did not.[40]

Comparison between techniques

From the studies included in this review, Babademez et al. is the only author to carry out a randomized study between isolated TORS and coblation surgery.[13] They found similar results in ESS, AHI and complication rate.

Huntley et al. compared upper airway stimulation (UAS) against TORS. They reported a lower complication rate, and higher curation rate with the use of UAS.[14]

Fibbi et al. compared lingual suspension to TBRF and observed similar results for polysomnogram data, but a higher complication rate for lingual suspension suture.[6]

Lastly, Hou et al. compared SMILE through a ventral vs a dorsal approach; they obtained similar results regarding polysomonogram data, but a lower complication rate for the ventral approach.[23]

Limitations

While the initial data is encouraging, as with any systematic review, the conclusions reached by this systematic review and meta-analysis were limited and did not enable us to generate conclusive results due to the heterogeneity of the included papers.

Only one paper could be included in the tongue base ablation group, which limit our ability to compare it with other techniques.

Lastly, the results are influenced by differences in patient selection, surgical technique and evaluation methodology among the selected studies. Therefore, findings herein observed may only suggest future research hypothesis, but the heterogeneity of the included papers does not allow for solid conclusions.

Conclusions

The available evidence suggests that minimally invasive base of tongue procedures may present a wide spectrum of complication rates, ranging from 4.4% in tongue base radiofrequency up to 42.42% in tongue base ablation.

This data suggests, furthermore, that prophylactic antibiotics may reduce complication rates, while steroids may increase them.

The heterogeneity amongst the included studies prevents us from obtaining solid conclusions.

Authors' contribution

Christian Calvo-Henriquez MD: conception, data search; data extraction; data analysis; manuscript draft writing; revision and final approval of the manuscript.

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Robson Capasso MD; PhD; FAASM: conception, manuscript draft writing; revision and final approval of the manuscript.

Carlos Martin-Martin MD, PhD: conception, manuscript draft writing; revision and final approval of the manuscript.

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Conflict of interest

The authors declare not to have any conflict of interest.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.otorri.2021.10.006.

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