

## Microsurgical Anatomy of the Terminal Hypoglossal Nerve Relevant for Neurostimulation in Obstructive Sleep Apnea.

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### Abstract

#### BACKGROUND:

Neurostimulation of the hypoglossal nerve has shown promising results in the treatment of obstructive sleep apnea. This anatomic study describes the detailed topography of the hypoglossal nerve's motor points as a premise for super-selective neurostimulation in order to optimize results and minimize the risk of complications related to main nerve trunk manipulation.

#### METHODS:

Thirty cadaveric hypoglossal nerves were dissected and characterized by number of branches, arborization pattern, and terminal branch motor point location. For each motor point, the distance to cervical midline (x axis), distance to posterior aspect of the symphysis (y axis), and depth from the plane formed by the inferior border of symphysis and anterior border of hyoid (z axis) were recorded.

#### RESULTS:

The average number of distal branches for each hypoglossal nerve was found to be  $9.95 \pm 2.28$ . The average number of branches per muscle was found to be  $3.3 \pm 1.5$  for the hyoglossus muscle,  $1.8 \pm 0.9$  for the geniohyoid muscle, and  $5.0 \pm 1.6$  for the genioglossus muscle. It was found that branches to the genioglossus and geniohyoid muscles were located closer to midline (relative lengths of  $0.19 \pm 0.07$  and  $0.19 \pm 0.05$ , respectively) while hyoglossus branches were located more laterally ( $0.38 \pm 0.10$  relative length). On the y-axis, the branches to the genioglossus were the most anterior and therefore closest to the posterior symphysis of the mandible (relative length of  $0.48 \pm 0.11$ ), followed by the geniohyoid ( $0.66 \pm 0.09$ ), and the hyoglossus ( $0.76 \pm 0.16$ ). The branches to the geniohyoid were the most superficial (relative length of  $0.26 \pm 0.06$ ), followed by the genioglossus ( $0.36 \pm 0.09$ ), and finally, the hyoglossus branches ( $0.47 \pm 0.11$ ), which were located deeply.

#### CONCLUSION:

A topographical map of the hypoglossal nerve terminal motor points was successfully created and could provide a framework for the optimization of the neurostimulation techniques.

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#### KEYWORDS:

Electrode placement; hypoglossal anatomy; hypoglossal nerve; microsurgical anatomy; neurostimulation; obstructive sleep apnea; upper airway stimulation

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## **Hypoglossal nerve stimulation rescue surgery after multiple multilevel procedures for obstructive sleep apnea.**

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### **Abstract**

Hypoglossal nerve stimulation (HNS) is a new procedure offered for the treatment of moderate-to-severe obstructive sleep apnea (OSA) that has been shown to decrease the severity and symptoms of OSA in select patients. We report on a case of a patient with persistent symptoms and findings of OSA despite a history of multiple multilevel procedures, including an uvulopalatopharyngoplasty (UPPP) with revision, a genioglossus advancement, and a maxillomandibular advancement. The patient then underwent HNS with significant improvement of his symptoms and severity. The success of this patient's HNS surgery demonstrates that we need to examine where HNS fits into the approach to surgery for OSA. There could be benefit to considering cranial nerve stimulation earlier than conventional approaches for select patients.

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## **Hypoglossal nerve stimulation in the treatment of obstructive sleep apnea: A systematic review and meta-analysis.**

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### **Abstract**

## **OBJECTIVES/HYPOTHESIS:**

Poor adherence to continuous positive airway pressure treatment in obstructive sleep apnea (OSA) adversely affects the effectiveness of this therapy. This study aimed to systematically review the evidence regarding the efficacy and safety of hypoglossal nerve stimulation as an alternative therapy in the treatment of OSA.

## **DATA SOURCES:**

Scopus, PubMed, and Cochrane Library databases were searched (updated through September 5, 2014).

## **METHODS:**

Studies were included that evaluated the efficacy of hypoglossal nerve stimulation to treat OSA in adults with outcomes for apnea-hypopnea index (AHI), oxygen desaturation index (ODI), and effect on daytime sleepiness (Epworth Sleepiness Scale [ESS]). Tests for heterogeneity and subgroup analysis were performed.

## **RESULTS:**

Six prospective studies with 200 patients were included in this review. At 12 months, the pooled fixed effects analysis demonstrated statistically significant reductions in AHI, ODI, and ESS mean difference of -17.51 (95% CI: -20.69 to -14.34); -13.73 (95% CI: -16.87 to -10.58), and -4.42 (95% CI: -5.39 to -3.44), respectively. Similar significant reductions were observed at 3 and 6 months. Overall, the AHI was reduced between 50% and 57%, and the ODI was reduced between 48% and 52%. Despite using different hypoglossal nerve stimulators in each subgroup analysis, no significant heterogeneity was found in any of the comparisons, suggesting equivalent efficacy regardless of the system in use.

## **CONCLUSIONS:**

This review reveals that hypoglossal nerve stimulation therapy may be considered in selected patients with OSA who fail medical treatment. Further studies comparing hypoglossal nerve stimulation with conventional therapies are needed to definitively evaluate outcomes.

## **LEVEL OF EVIDENCE:**

NA

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## **KEYWORDS:**

Hypoglossal nerve stimulation; sleep apnea

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**Upper Airway Stimulation for OSA: Early Adherence and Outcome Results of One Center.**

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## **Abstract**

### **OBJECTIVE:**

To review outcome measures and objective adherence data for patients treated with hypoglossal nerve stimulation (HNS) therapy for moderate to severe obstructive sleep apnea (OSA).

### **STUDY DESIGN:**

Case series with chart review.

### **SETTING:**

Academic sleep medicine center.

### **SUBJECTS AND METHODS:**

The first 20 implanted patients to complete postoperative sleep laboratory testing were assessed. All patients had moderate to severe OSA, were unable to adhere to positive pressure therapy, and met previously published inclusion criteria for the commercially available implantable HNS system. Data included demographics, body mass index (BMI), apnea-hypopnea index (AHI), Epworth Sleepiness Score (ESS), nightly hours of device usage, and procedure- and therapy-related complications.

### **RESULTS:**

Mean age was  $64.8 \pm 12.0$  years, with 50% female. Mean BMI was unchanged postoperatively ( $26.5 \pm 4.2$  to  $26.8 \pm 4.5$  kg/m<sup>2</sup>;  $P > .05$ ). Mean AHI ( $33.3 \pm 13.0$  to  $5.1 \pm 4.3$ ;  $P < .0001$ ) and mean ESS ( $10.3 \pm 5.2$  to  $6.0 \pm 4.4$ ;  $P < .01$ ) decreased significantly. Seventy percent (14/20) of patients achieved a treatment AHI  $<5$ , 85% (17/20) an AHI  $<10$ , and 95% (19/20) an AHI  $<15$ . Average stimulation amplitude was  $1.89 \pm 0.50$  V after titration. Adherence monitoring via device interrogation showed high rates of voluntary device use (mean  $7.0 \pm 2.2$  h/night).

### **CONCLUSION:**

For a clinical and anatomical subset of patients with OSA, HNS therapy is associated with good objective adherence, low morbidity, and improved OSA outcome measures. Early results at one institution suggest that HNS therapy can be implemented successfully into routine clinical practice, outside of a trial setting.

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### **KEYWORDS:**

hypoglossal nerve stimulation; obstructive sleep apnea; sleep surgery; upper airway stimulation

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## **Efficacy of Upper Airway Stimulation on Collapse Patterns Observed during Drug-Induced Sedation Endoscopy.**

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### **Abstract**

#### **OBJECTIVE:**

To describe upper airway collapse patterns observed on drug-induced sedation endoscopy (DISE) during screening for a clinical trial and to evaluate the impact of collapse patterns found on preoperative DISE on response rates to upper airway stimulation (UAS) therapy.

#### **STUDY DESIGN:**

Retrospective review of an ongoing prospective multi-institutional cohort study.

#### **SETTING:**

Twenty-two participating institutions of the STAR trial.

#### **SUBJECTS AND METHOD:**

In total, 222 subjects were screened with DISE to determine eligibility for an implantable UAS device. Supine laryngoscopy was performed during moderate sedation (propofol and/or midazolam). Airway collapse pattern and severity were graded at 4 levels, including velum, oropharynx, tongue base, and epiglottis (VOTE classification). Patients with complete concentric collapse (CCC) at the velum were excluded from implantation.

#### **RESULTS:**

The CCC at the velum was observed in 52 (23%) of screened subjects, and these subjects were subsequently excluded from implantation. Of the 170 subjects without CCC at the velum, 126 (77%) underwent implantation: 121 (96%) had multilevel collapse and 5 (4%) had single-level collapse. When comparing preimplantation DISE findings, UAS responders at 12 months had lower baseline VOTE scores compared with therapy nonresponders.

#### **CONCLUSION:**

Drug-induced sedation endoscopy is an efficient and safe method for determining UAS eligibility and has the potential to identify UAS nonresponders. Most patients had multilevel airway collapse, illustrating the limitations of single-level upper airway surgery in treating obstructive sleep apnea. Upper airway stimulation is effective therapy for most patients with multilevel airway collapse; however, patients with complete anterior-posterior or lateral soft palate and/or epiglottic collapse may be at increased risk of therapy failure.

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#### **KEYWORDS:**

drug-induced sedation endoscopy; drug-induced sleep endoscopy; obstructive sleep apnea; sedation; sleep surgery; sleep-disordered breathing; upper airway stimulation

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