A novel hypoglossal nerve stimulation approach restores upper airway function and airflow to therapeutic CPAP levels in people with obstructive sleep apnea

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Background

- Hypoglossal nerve stimulation provides efficacious therapy with high compliance for selected people with obstructive sleep apnea (OSA).

- Currently, hypoglossal nerve stimulation requires a surgical procedure to implant a stimulating lead using a cuff around or proximal to the hypoglossal nerve typically also with a sensing lead to the respiratory pump muscles.

- This proof-of-concept study aimed to determine the effect of an alternative, less-invasive approach to stimulate the hypoglossal nerve using a multi-electrode array implanted using a simpler percutaneous, ultrasound-guided approach.

Methods

- Participants were instrumented with EEG, submental chin EMG, epiglottic pressure sensor, nasal mask and pneumotachograph.

- Following propofol sedation, ultrasound was used to identify the hypoglossal nerve and to guide percutaneous placement of a temporary electrode array implant.

- Continuous positive airway pressure (CPAP) was used to maintain airway patency and transiently reduce pressure to cause flow limitation or airway obstruction for ~9 inspiratory breaths/efforts with stimulation applied during breaths 4 to 6.

- Active upper airway collapsibility (Pcrit) was measured using step-wise reductions in pressure until airway collapse occurred with vs. without sustained stimulation (n=4 participants).
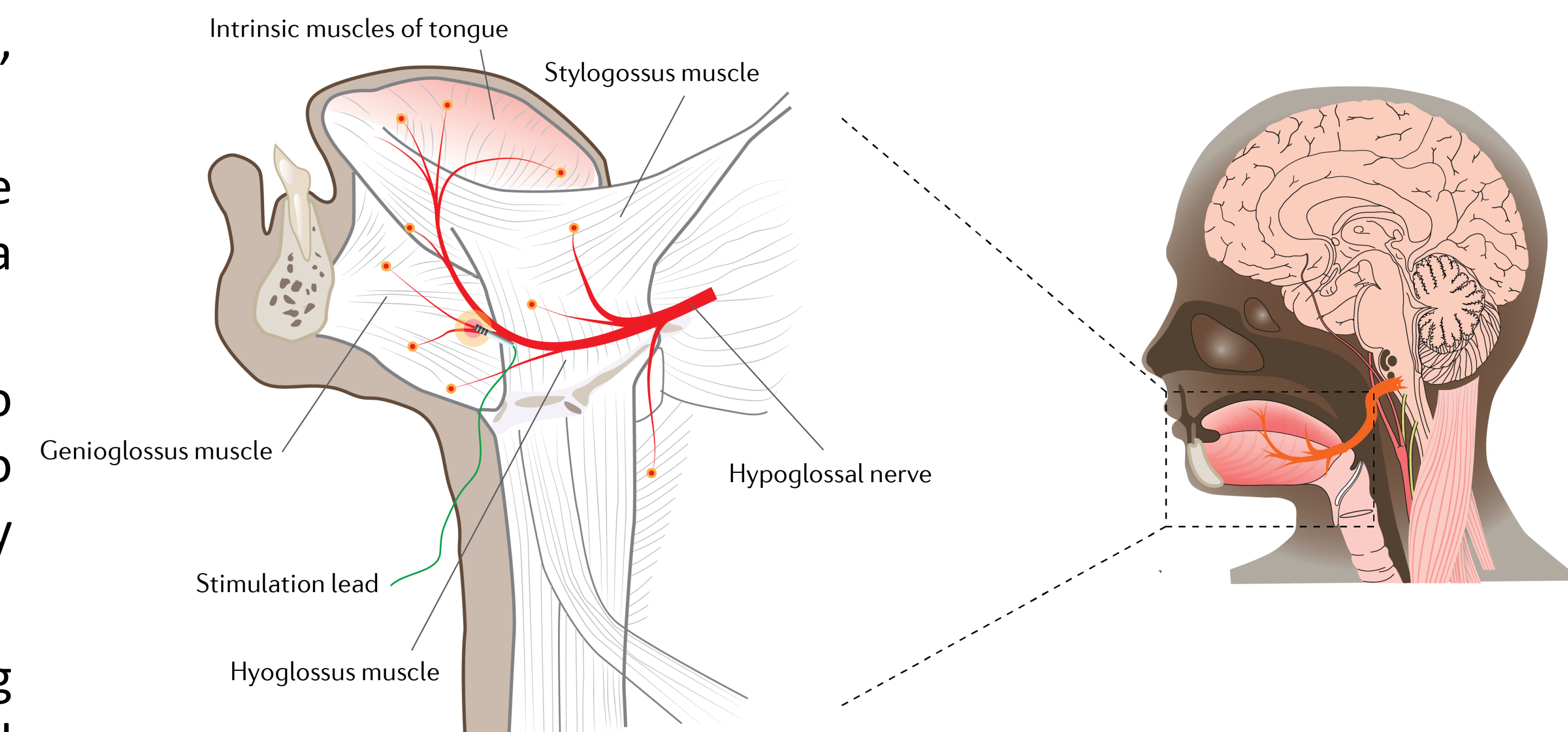

Figure 1: Illustration of the temporary electrode array implant used to deliver electrical stimulation to the distal hypoglossal nerve.

Results

- 14 (2 female) mostly obese (BMI=30±3 Kg/m^2) participants aged 49±14 years with severe OSA (AHI= 30±16 events/h) were studied (mean±SD).

- Substantial airflow recovery was achieved with an average of 3±0.8mA stimulation.
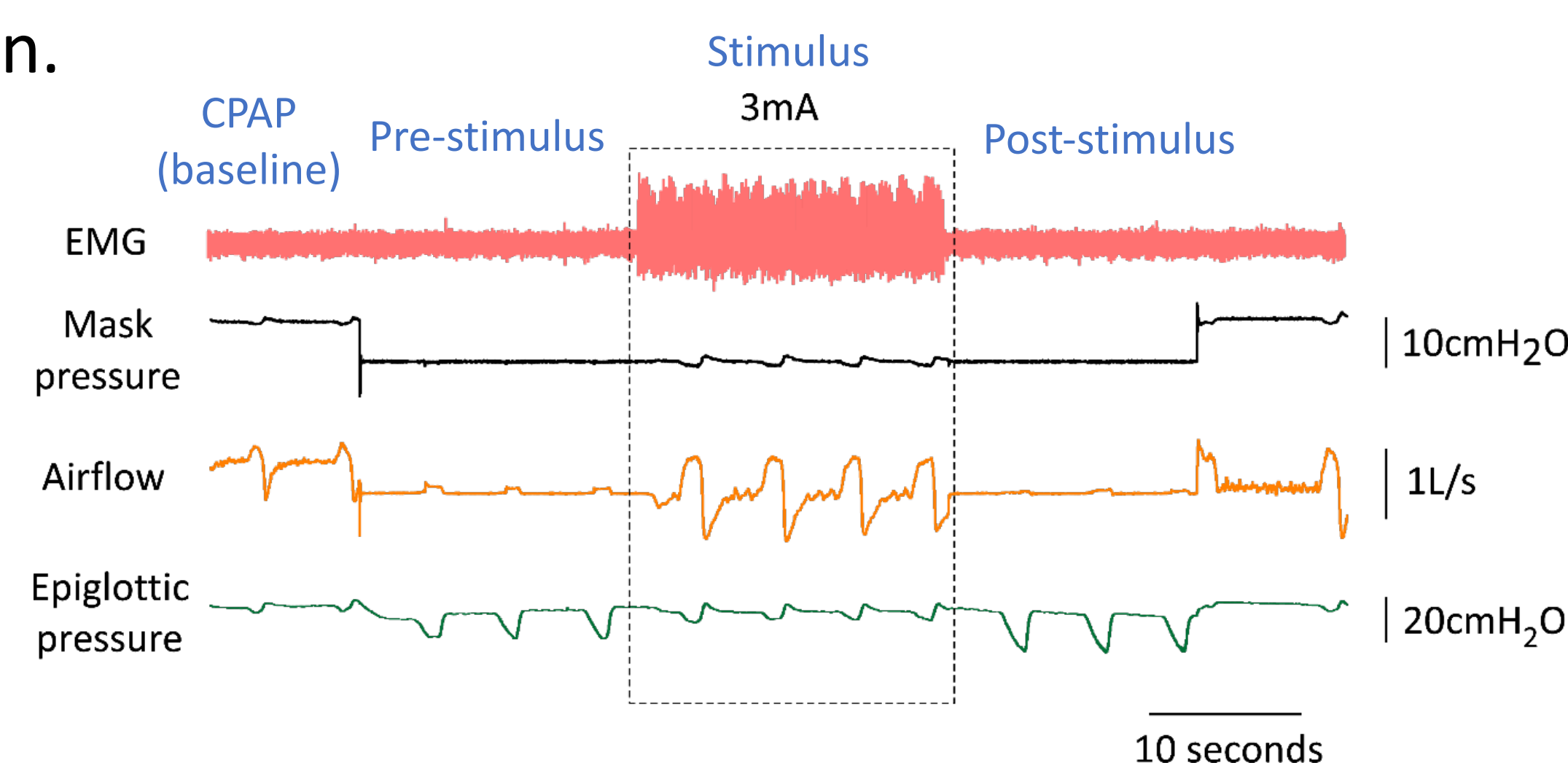

Figure 2: Raw data from a 63-year old male, BMI 29 Kg/m^2 and AHI of 41 events/h showing a single CPAP level reduction from 10 to 6 cmH$_2$O leading to reduced airflow which was restored during brief hypoglossal nerve stimulation and then returned following cessation of stimulation.
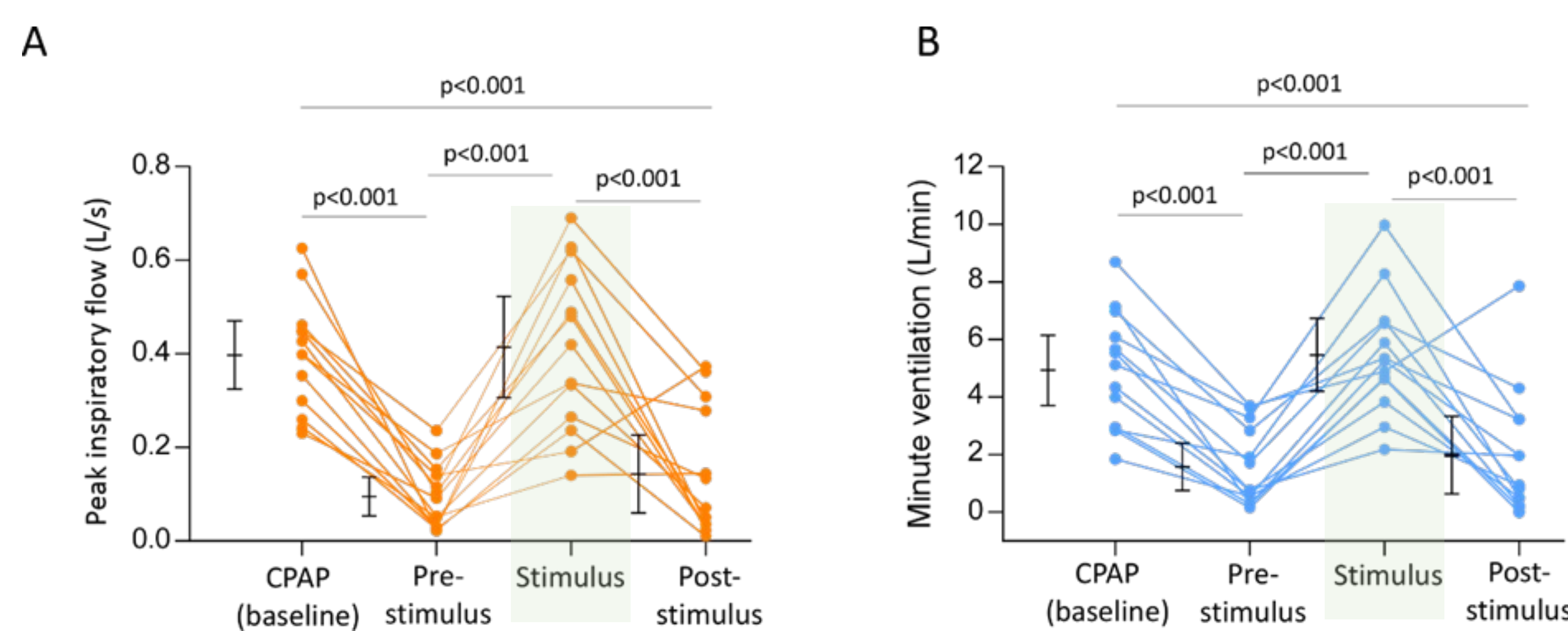

Figure 3: Individual and mean±95%CI 3-breath averages of (A) peak inspiratory airflow and (B) minute ventilation during baseline (on CPAP), pre-stimulus following acute CPAP reduction, during acute hypoglossal nerve stimulation (green shading) and post-stimulus. Data reflect stimulation trials from each participant once the electrode was positioned optimally to yield the highest peak flow responses to the stimulus.
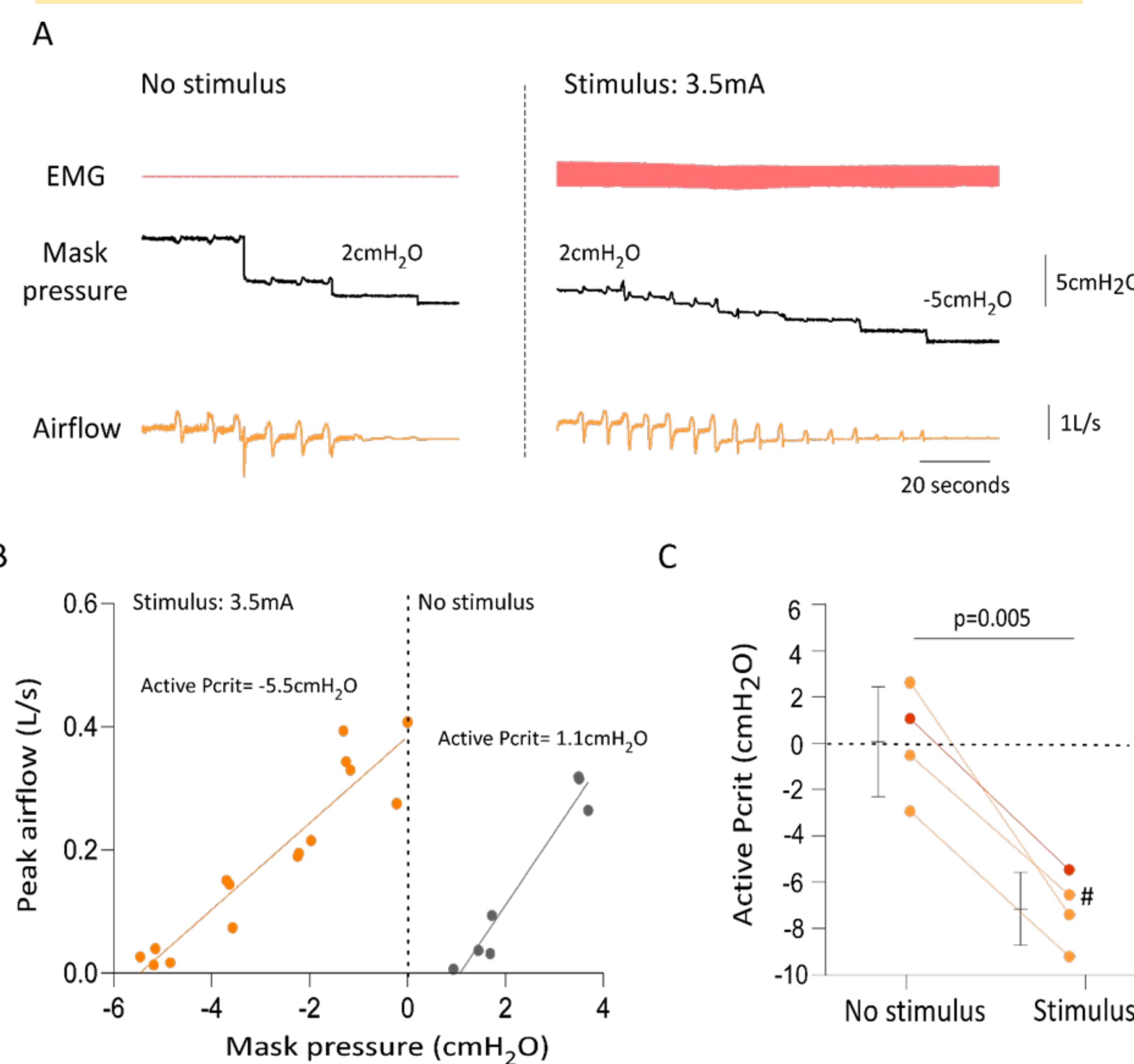

Figure 4: Raw data showing airflow responses during active Pcrit with no stimulus applied to the hypoglossal nerve vs. application of sustained stimulation (A). Two active Pcrit regressions (B) from the raw data presented in (A). Individual and group data with mean±SD (C) for all participants with active Pcrit measured with and without stimulus. Participant in red is the individual with data from (A) and (B).

represents a participant in whom we were unable to quantify active Pcrit during the no stimulus condition. Instead, here we show the difference between 3.5mA stimulus (which was less effective- labelled "No stimulus") vs. 4mA stimulus.

Table 1: Comparison of respiratory parameters between airflow measured on CPAP for ~30 seconds prior to a reduction in CPAP and airflow responses before, during and after the stimulus (n=13).

	CPAP (baseline)	Pre-stimulus	Stimulus	Post-stimulus
Breathing frequency (breaths/min)	13.0±3.2	15.3±4.8*	15.2±4.9*	13.7±4.6#
Tidal volume (L)	0.4±0.2	0.1±0.1*	0.4±0.1	0.14±0.14*
Mean inspiratory flow (L/s) *(Tidal volume/inspiratory time)*	0.2±0.1	0.1±0.1*	0.2±0.1	0.1±0.1*#
Inspiratory time (s)	2.0±0.7	2.3±0.8	2.1±0.8¥	2.5±1.1*
Expiratory time (s)	3.1±1.1	2.2±1.0*	2.4±1.2*	3.7±4.7
Mask pressure (cmH$_2$O)	12.4±3.4	4.2±3.1*	4.2±3.0*	4.2±3.0*

*p<0.05 compared to CPAP (baseline)
#p<0.05 compared to pre-stimulus
¥p<0.05 compared to CPAP (baseline)

Summary

This novel, percutaneous hypoglossal nerve stimulation approach markedly improves:

- Airflow in 13 out of 14 participants.

- Peak airflow and minute ventilation to levels equivalent to airflow on therapeutic CPAP.

- Upper airway collapsibility (active Pcrit) by ~-7cmH$_2$O.