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ORIGINAL ARTICLE

Long-term Effect of Uvulopalatopharyngoplasty on Driving Performance

Per-Olle Haraldsson, MD; Christer Carenfelt, MD; Michael Lysdahl, MD; Jan Törnros, MA

Objective: It has been questioned whether the effect of uvulopalatopharyngoplasty lasts as years go by. From a previous study it is known that patients with severe rhonchopathy, complaining of sleepiness at the wheel, improve their vigilance and driving performance immediately following uvulopalatopharyngoplasty, but is this effect persisting?

Design: In a cohort study, the long-term effect of surgical treatment on driving vigilance was evaluated on 13 middle-aged (median, 52 years) male patients and five matched controls. Three to 4 years postoperatively, they were subjected to a boring 90-minute-long retest in an advanced driving simulator and daytime polysomnography, identical to those performed preoperatively. Factors measured were brake reaction time, lateral position

deviation, and off-road incidents. The patients were also asked to assess their driving skills on a self-report and their vigilance on a visual analogue scale.

Results: All but one patient reported themselves as being more vigilant and safe drivers following surgery. Objective results showed that the initial improvement in brake reaction time, lateral position deviation, and number of off-road incidents was sustained, but not always in concordance with the apnea index.

Conclusion: The positive effect of uvulopalatopharyngoplasty on vigilance and driving performance remains after 4 years. This may have a substantial impact on traffic safety.

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A DANGEROUS tendency to fall asleep while automobile driving is a common complaint of patients with intermittent upper airway obstruction during sleep. Some 50% of patients with severe rhonchopathy reported this hazard, compared with less than 1% of matched controls.¹ This group also performs poorly in psychomotor and cognitive tests,²⁻⁴ and it has been reported that automobile accidents,^{5,6} especially single-car accidents,¹ are overrepresented in drivers suffering from the disorder.

When the respiratory obstruction is generated at the level of the oropharynx, a uvulopalatopharyngoplasty (UPPP) should be considered. Following UPPP, a 50% reduction of apnea index (AI) can initially be expected in 50% to 80% of patients,⁷⁻⁹ even if it has a tendency to increase as years go by, especially in overweight subjects.¹⁰

The long-term effect of UPPP on vigilance and psychomotor function is yet unknown. To study this, a driving simulator test, developed at the Swedish Road and

Traffic Research Institute, Linköping, was used, enabling detection of drivers suffering from impaired vigilance at the wheel.¹¹ Patients with severe rhonchopathy, complaining of sleepy spells while driving, had participated in test drives preoperatively. These patients were retested more than 3 years later in an identical drive to see whether the positive effect noticed 3 months after UPPP would persist. The driver's self-assessment of vigilance and driving capability was evaluated parallel to the trials.

RESULTS

All patients reported a reduction of sleepy spells at the wheel, even if it still was occurring "often" in two. All except one (patient 4) reported that their driving was more vigilant and safer than before surgery. The self-reported sleepiness score de-

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See Subjects and Methods on next page

SUBJECTS AND METHODS

DEFINITIONS AND SELECTION OF SUBJECTS

Fifteen male drivers, aged 30 to 69 years, who were habitually sleepy at the wheel, were consecutively selected from patients with the clinical triad of habitual symptoms that characterize severe rhonchopathy, including sleep apnea syndrome—heavy snoring, sleep disturbances (a history of sleep apneas and/or midsleep awakenings, but no difficulty in falling asleep), and excessive daytime sleepiness with sleep attacks.^{12,13} On a validated questionnaire,¹⁴ symptoms were neglected if scored "never" or "seldom," but they were included as habitual if they occurred "often" or "always." Ten age-matched male volunteers, with similar experience of car driving, were selected as controls. Although they were not subjected to sleep studies, they denied hypersomnia at the wheel and habitual occurrence of symptoms associated with the disease, except possible snoring. Thus, they were unlikely to suffer from sleep apnea.¹⁴ Informed consent was obtained from all participating subjects.

At the time of the long-term postoperative trial, 13 of 15 patients and five of 10 controls (median age, 52 years [range, 45 to 64 years] vs 50 years [range, 48 to 63 years]) were willing and fit to participate. Two patients unable to do so had non-sleep apnea syndrome-related disorders, and one of the controls had to be excluded because symptoms of sleep apnea syndrome developed. Primary performance data of the controls, selected for evaluation of consistency, did not differ from those not retested. Postoperative clinical success regarding traffic hazard was defined as a denial (never, seldom) of recurrent sleepy spells at the wheel on the self-report.

CLINICAL AND POLYSOMNOGRAPHIC EXAMINATIONS

All patients had a routine preoperative ear, nose, and throat examination, also including fiberoptic rhinolaryngoscopy during voluntary snoring and Müller's maneuver, and based on these findings, the level of obstruction could be classified according to Fujita.¹⁵ Furthermore, all patients were examined by a neurologist to exclude narcolepsy. They were subjected to a standard electrocardiogram and static cephalometry,¹⁶ as well as a body mass index (BMI) calculation¹⁷ preoperatively. Blood pressure was read before each test. Daytime polysomnography (DPSG) was performed following 1 night of sleep deprivation.^{18,19} Total sleeping time; sleep stages; number and duration of obstructive, central, or mixed apneas; and total apnea time were calculated.

DRIVING SIMULATOR TEST

The advanced driving simulator at the Swedish Road and Traffic Research Institute was used (**Figure**). The equipment, computer program, and the test run have been described previously.¹¹ A monotonous drive at about 90 km/h (55 mph) on a one-lane, narrow (3.5 m) curved road at twilight, intended to provoke sleepiness, was programmed, during which the driving performance was measured. After having had lunch, all subjects were instructed to drive for a period of 90 minutes. During this time they were sub-

jected to 25 visual brake reaction stimuli. The lateral position of the vehicle was sampled twice per second, and the SD was calculated for each 5-minute period. Performance data were collected during the total drive and subsequently subjected to analysis. During the test, drivers were observed and videotaped, using infrared-sensitive television. Factors measured included brake reaction time (BRT), lateral position deviation (LPD), and frequency of off-road incidents.¹¹ Mean values and 90th percentiles of BRT and LPD were calculated. At the late retest, an identical data program was used, but the simulator cabin at the institute had been upgraded from one car (Saab 900) to another (Saab 9000), with a similar modification of the vehicle model.

SURGICAL PROCEDURE

All patients had a UPPP performed under general anesthesia, using a slight modification of the technique described by Dickson and Blokmanis.²⁰ Three patients (cases 2, 4, and 13) who complained of decreased nasal patency also had their nasal obstruction corrected. Obese subjects were told to lose weight, and all were informed that weight gain would jeopardize the effect of UPPP.

EVALUATION OF VIGILANCE

All subjects were asked to indicate their current sleepiness on a 10-cm-long visual analogue scale, with 0 being alert to 10 being asleep, three times daily (at 8 AM, at noon, and at 8 PM) for a week before the trial. The sum of sleepiness for each week was calculated in an arbitrary unit equal to centimeters. Each patient also had to state whether he considered himself a poorer, equal, or better driver than before surgery.

DESIGN AND TESTING PROCEDURE

All patients were subjected to a preoperative test drive, which was compared with that of matched controls. On average, 45 months (range, 35 to 49 months) following surgery, symptoms were reassessed using an identical questionnaire and all, except two patients with a positive DPSG (AI ≥ 5) preoperatively, were reexamined. Patients and control subjects were given an individually identical retest. To exclude possible impact on the results from age and the new simulator car, the BRT and LPD from the patients were not only compared with the preoperative values but they were also related to the results of the control drivers (difference for patients minus difference for controls). Driving performance data for all tests were assessed without knowledge of the questionnaire-evaluated clinical outcome.

STATISTICS

For comparison of BRT, LPD, and visual analogue scale preoperatively and postoperatively (related samples), Wilcoxon Signed Rank Test was used. For comparison of number of drivers off-road, preoperatively and postoperatively, χ^2 test with Yates' correction was used, while the number of such episodes preoperatively and postoperatively was evaluated with a Sign Test. Impact of cofactors was evaluated by comparing the change in BRT and LPD for patients and retested control drivers by use of the Mann-Whitney *U* Test (unrelated samples).

Drawing demonstrating the main features of the Swedish Road and Traffic Research Institute car-driving simulator.

creased from a preoperative mean value of 137.9 to 86.8 ($P < .01$) in the 13 retested patients (**Table 1**). The average BMI was unchanged from 30.1 (range, 25.5 to 35.3; $SD \pm 3.6$) to 30.0 (range, 26.0 to 37.6; $SD \pm 4.4$) preoperatively. The BRT, LPD, and off-road incidents before and a mean of 45 months (range, 35 to 49 months) after surgery are given in **Table 2** and **Table 3**. The mean BRT improved 0.44 second postoperatively, which translates to an average of 11-m shortening of the brake reaction distance at 90 km/h. All those patients who drove off the road preoperatively were found to have decreased their number of incidents or had none at all at the long-term retest.

Driving performance of patients improved, and the difference was significantly greater than that for retested control drivers (BRT, $P < .05$; and LPD, $P < .01$). Long-term results, however, were similar in both BRT and LPD in both patients and controls (**Table 4**). No correlation was found between AI and the visual analogue scale (Spearman correlation coefficient, $< .50$) or between AI and BRT (90th percentiles) preoperatively (Spearman correlation coefficient, $< .33$).

COMMENT

The present study shows that the initial improvement of simulated driving performance, found some months after UPPP,²⁰ also substantially remained long-term. The advanced driving simulator has been recognized as a very sensitive tool to detect central nervous system depression,^{21,22} and it gives an opportunity to test psychomotor function in an environment similar to that in which patients had reported their problems, ie, at the wheel. Moreover, it permits standardized test conditions and allows driving assessment without any danger.

Table 1. Self-assessment of Daytime Sleepiness*

	Preoperative	Postoperative	
		3 mo	>3 y
Patients			
1	109.0	52.0	114.0
2	122.0	87.0	81.0
3	153.0	72.0	127.0
4	123.0	120.0	115.0
5	153.0	24.0	24.0
6	114.0	59.0	77.0
7	179.0	81.0	84.0
8	127.0	124.0	106.0
9	196.0	98.0	90.0
10	145.0	45.0	21.0
11	142.0	38.0	29.0†
12	143.0	102.0	116.0
13	119.0	45.0	87.0
14	121.0	21.0	21.0‡
15	110.0	72.0	87.5
Average†	137.1	69.3	78.6
Controls			
1	64.5	...	84.0
2	78.5	...	56.0
3	44.5	...	98.5
4	57.0	...	58.0
5	49.0	...	84.0
Average	58.7	...	76.1

*The subjects scored on a 10-cm-long visual analogue scale 3 times daily (8 AM, noon, and 8 PM) for 7 days, where 0 stands for alert and 10 cm means asleep. All figures were summarized to arbitrary units equal to centimeters.

†The decrease in sleepiness remained highly significant ($P < .001$) at the long-term follow-up. Driver 1 had early working hours (from 5 AM) at the long-term follow-up.

‡Drivers 11 and 14 could not participate.

Although an identical data program was used, the new upgraded simulator used for retesting may have influenced the results. The slight improvement in LPD and deterioration of BRT in controls suggest that this may be the case. However, this would not change the conclusions. The improvement of BRT and LPD seen in patients remained significant even when possible improvement in retested controls was subtracted. Furthermore, long-term results showed the driving performance attained by both patients and control subjects to be about the same.

On initial testing 3 months postoperatively,²⁰ three of 15 patients reported persistent sleepiness at the wheel, and these were of special interest. The first one, an obese taxi driver (patient 4), had failed to lose weight, but was successfully treated with nasal continuous positive airway pressure, although it was not used the nights before the present test drive. The second patient (patient 8), had a BMI exceeding 37 and the UPPP did not change his driving vigilance until he had lost weight to a BMI of about 32. He claims that he now can drive 500 km without need of pulling off the road for a nap, which is a 10 times longer distance than preoperatively. The third patient (patient 13), an executive, admitted heavy evening drinking habits. The rhonchopathy and the daytime sleepiness ameliorated after a radical change of lifestyle.

Table 2. Individual 90th Percentile (P90) Results of Brake Reaction Time (BRT) and Lateral Position Deviation (LPD) Before and an Average of 45 Months (Range, 35 to 49 Months) After Uvulopalatopharyngoplasty.

	BRT, s		LPD, cm		Off-road incidents		AI From DPSG*	
	Before	After	Before	After	Before	After	Before	After
Patients								
1	2.78	2.48	26.8	20.3	1	0	0	...
2	2.13	2.10	59.7	39.4	6	3	23	14
3	...	2.00	31.6	17.6	0	0	40	41
4	1.92	2.12	46.1	32.7	0	0	4	...
5	1.78	1.58	45.9	29.7	0	0	50	...
6†	2.48	3.04	...	20.0	0	0	25	44
7	2.74	2.14	89.4	36.7	69	1	49	21
8	2.64	1.80	56.3	25.8	8	0	50	59
9	2.40	1.46	33.8	18.8	5	0	57	66
10	5.44	2.14	35.3	23.9	0	0	69	0
11‡	4.52	...	32.3	...	0	...	14	14
12	3.50	2.50	44.9	27.8	2	0	31	0
13	2.70	2.34	44.6	22.0	3	0	105	55
14‡	2.80	...	37.8	...	0	...	103	...
15	2.04	2.28	55.5	15.6	7	0	66	53
Controls								
1	1.99	1.54	40.0	25.7	2	0	...	...
2	1.62	2.08	33.2	28.4	0	0	...	...
3†	1.44	3.84	35.0	30.3	0	0	...	...
4	1.30	1.48	23.8	23.3	0	0	...	...
5	1.44	2.10	31.8	25.8	0	0	...	...

*AI indicates apnea index; DPSG, daytime polysomnography.

†These drivers had thick spectacle frames and missed three peripheral BRT stimuli each. The BRT and LPD values are missing for patients 3 and 6, respectively.

‡Drivers 11 and 14 could not be retested due to non-sleep apnea syndrome-related medical disorders.

Table 3. Results From Patients' Test Drive, Comparing Brake Reaction Time (BRT), Lateral Position Deviation (LPD), and Off-Road Incidents Before and an Average of 45 Months After Uvulopalatopharyngoplasty*

	Preoperative Test	P	Long-term Retest
Mean BRT, s	1.88±0.61	<.05†	1.44±0.61
P90 BRT, s	2.71±0.98	<.05†	2.16±0.43
Mean LPD, cm	40.0±10.6	<.01†	22.1±5.74
P90 LPD, cm	47.5±16.7	<.01	25.9±7.60
Drivers off-road, n	8	<.05‡	2
Off-road incidents, median	1 (0-69)	<.01§	0 (0-3)

*P90 indicates 90th percentile. Unless otherwise specified, all values are mean±SD.

†Wilcoxon Signed Rank Test.

‡χ² test.

§Sign Test.

The AI, as measured by DPSG, related neither to the preoperative BRT nor to the improvement seen in BRT, LPD, or off-road incidents following surgery. It might be argued that DPSG has low validity and a too-wide range of outcome, compared with all-night polysomnography,¹⁴ but even in this instance, daytime

Table 4. Brake Reaction Time (BRT) and Lateral Position Deviation (LPD) at the Long-term Postoperative Trial, Comparing 13 Patients and Five Retested Controls*

	Patients	Controls
Mean BRT, s	1.44±0.61	1.38±0.26
P90 BRT, s	2.16±0.43	2.21±0.95
Mean LPD, cm	22.1±5.74	21.7±1.99
P90 LPD, cm	25.9±7.60	26.7±2.70
Drivers off-road, n	2	0
Off-road incidents, median	0 (0-3)	0

*P90 indicates 90th percentile. The differences between the two groups (P values) are nonsignificant. Unless otherwise specified, values are mean±SD.

sleepiness shows a low correlation with AI.^{23,24} Furthermore, sleepiness may be caused by rhonchopathy, even without apnea.²⁵ The incongruity between a patient's subjective experience of well-being and the objective sleep data, indicating a persistent disorder, found in the present study and by others,¹⁰ has yet to be explained. Patients, unaware of these objective data, however, did report less awakenings and more refreshing sleep.

Findley et al²⁶ have shown that patients with sleep apnea treated with nasal continuous positive airway pressure also improve their performance when tested in a driving simulator. This improvement could be expected to remain as long as patients persevere with the treatment. Nasal continuous positive airway pressure is superior to UPPP in abolishing episodes of apnea, but this should not fool the physician into thinking that a prescription has cured the patient, since the long-term compliance is unreliable and has been found to be only 58% to 89%.²⁷⁻³⁰ As shown in the present study and by others,¹⁰ the feeling of vigilance most patients achieve after UPPP is independent of polysomnography findings. Therefore, from the standpoint of driving vigilance, UPPP is a reliable alternative that is not directly dependent on patient compliance.

The subjective assessment of daytime sleepiness in Table 1 showed a tendency to long-term impairment for some subjects even in the control group. We did not investigate this further. However, self-reported vigilance and driving skills showed a better correlation with the objective vigilance data than with the AI and indicated that a clinical history from the driver could forecast driving performance. The final answer to the benefit of UPPP to road safety, however, can first be given when it is possible to show that the improvement of subjective vigilance and simulated driving is reflected in a corresponding decrease in traffic accidents.

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