

Case Study of Obstructive Sleep Apnea and Methods of Treatment for a Professional Driver

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Abstract—This study evaluates obstructive sleep apnea treatment through a case study involving a 67-year-old male driver who had a successful continuous positive airway pressure (CPAP) treatment at home but experienced difficulties with traveling and dental care. There are many cheap sleep apnea and snoring devices available, but there is little professional advice on what kind of devices can help. Professional drivers receive yearly specialized medical care follow-up.

Keywords—Sleep, apnea patient, CPAP, professional driver.

I. INTRODUCTION

SLEEPING difficulties are increasing. Diagnosed obstructive sleep apnea (OSA) is a growing public health problem [1]. According to the American Academy of Sleep Medicine (AASM), OSA affects over 28 million adults in the US [2] and has been named as a cause of many motor vehicle collisions [1], [3].

The Commission Directives 2014/85/EU and 2006/126/EC of the European Parliament and of the Council give requirements on driving licenses [4]-[6]. According to 2014/85/EU: “11.4. Driving licenses may be issued to applicants or drivers with moderate or severe OSA syndrome who show adequate control of their condition and compliance with appropriate treatment and improvement of sleepiness, if any, confirmed by authorized medical opinion” and “11.5. Applicants or drivers with moderate or severe OSA syndrome under treatment shall be subject to a periodic medical review, at intervals not exceeding three years for drivers of group 1 and one year for drivers of group 2, with a view to establish the level of compliance with the treatment, the need for continuing the treatment and continued good vigilance.” [4]

The new directive has influenced the treatment of professional drivers with OSA. Dwarakanath et al. [7] have studied variability in clinicians’ opinions regarding fitness to drive in patients with obstructive sleep apnea syndrome (OSAS). They evaluated clinicians’ current practice for giving advice to patients with OSAS. They determined that there was a need for clearer guidance and to update the Driver and Vehicle Licensing Agency guidelines.

CPAP is among the most popular home treatments for OSA [8]. People are required to breathe air at positive pressure through a mask each night (for at least 4 h) [8]. Different

devices and accessories are available in the market, but they still are viewed unfavorably. [8]-[10] Bitterman et al. [8] reviewed available devices, identified problems and requirements, and suggested design concepts that may improve patient satisfaction, adherence, and quality of life. Their results indicate obstacles in the image and appearance of CPAP as a daily, life-time utility, in user capabilities, in performance and adaptability to bedroom design [8].

One possibility is to use oral appliances for the treatment of sleep disordered breathing [11], [12]. According to Ryan et al. [11], such devices can treat simple snoring, mild OSA, and moderate to severe OSA when CPAP therapy is intolerable and upper airway surgery is not suggested [11], [13].

When a patient cannot use CPAP devices, electrical stimulation of the upper airway dilator muscles is possible [14]-[16]. For example, Woodson et al. [15] studied the long-term (36-month) clinical and polysomnographic outcomes in an OSA cohort of 59 patients treated with cranial nerve upper airway stimulation. The authors concluded that cranial nerve stimulation for the treatment of moderate to severe OSA is a successful and appropriate long-term treatment of CPAP-intolerant individuals with moderate to severe sleep apnea [15].

A Finnish working group published Current Care Guidelines of Sleep Apnea (OSA in adults) in 2017 [17]. They based the clinical severity of sleep apnea on daytime drowsiness and sleep registration [17]-[19]:

- Light OSA: Appears only when stationary, not necessarily daily, and causes little harm to social and work life; saturated oxygen (SaO₂) average $\geq 90\%$ and minimum $\geq 85\%$; and apnea-hypopnea index (AHI) 5...15
- Moderate OSA: Daily when activity is low and the situation requires moderate concentration (e.g., driving a car, attending a meeting, watching movies); SaO₂ average $<90\%$ and minimum $\geq 70\%$; and AHI 16...30
- Severe OSA: For daily tasks that require activity or clear concentration (e.g., driving a car, conversation, eating, walking); causes significant harm to social life and work; SaO₂ average $<90\%$ and minimum $<70\%$; and AHI >30 .

The aim of this article is to discuss the status of a moderate AHI patient.

II. MEDICAL DEVICES

A. CPAP

CPAP is treated moderate to severe cases of OSA. CPAP creates positive pressure in mouth and throat area, and then helps breathing during sleep. It has a pump that gives positive pressure through air tube to a nasal or face mask worn by the

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patient. Fig. 1 shows an example of patient using a CPAP device.



Fig. 1 An example of patient with CPAP device

The CPAP system helps the airflow to lungs and prevents breathing pauses. For some people, the nose mask is not good, so the face mask is used. The face mask gives positive pressure to the airways, but simultaneously it presses lower jaw backwards, and then obstructs airway to the lungs.

B. Oral and Dental Appliances

Oral appliances can also work for people with sleep apnea [20]. These devices are more comfortable than wearing a mask, as they are portable and the subject can talk and drink water while wearing them. An oral appliance fits like a retainer. It works by keeping jaw and tongue in a forward position so that they cannot block the airway even after the airway muscles fully relax in deep sleep. Since people grind and clench while sleeping in order to reopen a collapsed airway, sleeping with an oral appliance can eliminate the need to grind and eventually temporomandibular (TMD) symptoms. A nightguard will protect the teeth from the forces of grinding but can increase grinding by increasing the blockage in the airway. An oral appliance treats the root cause—sleep apnea—thereby eliminating the need to grind in the first place.

Orthodontic appliances bring the mandible and tongue forward, keep the lower pharynx open and help breathing during sleep. For example, tongue retaining devices (TRD) and mandibular advancement appliances (MAA) are such devices.

Oral appliances are used only during sleep; they reposition the lower jaw, tongue, soft palate or uvula and maintain an unobstructed airway. They protrude the mandible, keep the tongue forward, and prevent upper airway collapse during sleep. They significantly reduce breathing pauses. They improve airflow for some patients with apnea. They reduce the snoring, but the disadvantages of oral appliances are that the reciprocal forces generated on the teeth and jaw by mandibular advancement splints result in dry mouth, gum soreness, salivation, tooth pain, headaches, and TMD problems [21].

For many people, dental devices are considered more comfortable than CPAP masks. CPAP users can have dry, itchy noses. Oral devices do not have these problems. There is less equipment to become entangled in or knock off during

sleep for patients who move a lot during sleep. There is significantly less equipment involved and the device is, therefore, is an easier system in traveling [22].

Dental appliances can help patients with mild sleep apnea (not recommended for moderate to severe sleep apnea), patients with primary snoring (in absence of sleep apnea), patients who have tried and failed at CPAP therapy, and patients who were unsuccessful with or refused surgeries, such as tonsillectomy, adenoidectomy, craniofacial operations, or tracheostomy. In combination with a CPAP device, these devices can reduce a patient's AHI for more tolerable air pressure settings.

Mouth devices can be bought custom-made or over the counter. Whatever type is chosen, there is a need to see a dentist to have it fitted. A mandibular advancement device (MAD) looks like a mouth guard that athletes wear. It snaps over the top and bottom teeth. This makes the lower jaw ease forward, which keeps the tongue and soft palate stable so that the airway stays open during sleep. Tongue-retaining devices work like a splint that holds the tongue in place to keep the airway open. Doctors do not prescribe it as often as the MAD. It can be harder to get used to and is less comfortable.

C. Tennis Balls to the Back of the Pajamas

Most sleep problems emerge when sleeping on back. And then the airway to the throat can be blocked. Sleeping on one's side may improve symptoms. To prevent rolling onto the back during sleep, some doctors suggest patients to pin a tube sock filled with a couple of tennis balls to the back of their pajamas.

D. Nerve Stimulation Devices

When the tongue and other tissue in the throat fall back and block the airway, a small device called a hypoglossal nerve stimulator can help [14]-[16].

E. New Possible Devices in the Future

Nukute [23] combines a tracheal sensor, an accelerometer, a pulse oximeter, and a secured cloud-based application into a novel method for screening and diagnosis of sleep apnea. Nukute makes AHI measurement more comfortable, accessible, and affordable. It can be used in clinics and home settings. It measures air flow via a tracheal sensor and SPO₂. It can be used simultaneously with a CPAP mask; it has a gravity meter that detects the sleeping position. A customized AHI report can be downloaded after completing a test.

III. AN EXAMPLE OF PATIENT

A. Case —67-Year-Old Man

The patient had been diagnosed in 2010 with moderate OSA. Total AHI was 18/h, sleeping on back AHI 59/h, average SaO₂ was 93%, and minimum SaO₂ was 80%. The patient weighed 93 kg. The treatment started by CPAP in 2011 and has been going well, since the patient has adapted to this treatment. A specialized nurse has been conducting the annual follow-up. The patient has a C-driving license, but he is not driving professionally. Other illnesses are tablet-treated diabetes II, hypercholesterolemia, hypertension, and idiopathic

trombocytopenic purple (ITP).

The patient came from sleeping clinics of the university hospital clinic for a doctor's evaluation. The main reason for the appointment was that the patient was using a bruxism rail over his upper teeth, and the dentist had diagnosed also lower teeth wear. The dentist had proposed a rail for the lower teeth but not a sleep apnea dental appliance. The dentist was wondering if the CPAP treatment was still possible after those rails. Now the CPAP-treatment works well. The patient uses CPAP system regularly and is satisfied with this treatment. However, the CPAP device is difficult to use while traveling and especially when there is no electricity; in such instances,

he uses no device at all.

At the moment, there are no alertness management problems. There are never naps during driving. The patient uses an automatic CPAP-device and a face mask. The status is good: patient is alert and well-reacting. His health data are as follows: height: 174 cm; weight: 94 kg; BMI: 31; ESS points: 2; GHQ-12 points: 2. CPAP-device information is as follows: autoSet CPAP-pressure limits 10-16 cmH₂O; EPR-level 2.95 percentile treatment pressure 13.9 cmH₂O; and maximum treatment pressure 15.1 cmH₂O; remaining AHI: 1.8; median usage hours 100 % per last month; and median usage: 6 h/night. Figs. 2-6 show the statistics.

Statistics

11.1.2018 - 15.1.2019		Device: AirSense 10 AutoSet (S/N: 23171880780)	
Device Settings			
Therapy Mode: AutoSet	EPR: FULL_TIME	EPR Level: 2,0 cmH2O	
EPR Enable: ON	EPR Patient Enable: ON	Ramp Enable: OFF	
Ramp Time: 5,0 Minutes	Essentials: ON	Response: STANDARD	
Minimum Pressure: 10,0 cmH2O	Maximum Pressure: 16,0 cmH2O		
Pressure - cmH2O			
Median: 11,4	95th Percentile: 13,7	Maximum: 15,2	
Leak - L/min			
Median: 1,2	95th Percentile: 22,8	Maximum: 51,6	
Respiratory Indices - events/hr			
Apnea Index: 1,1	Hypopnea Index: 0,7	AHI: 1,8	
Obstructive: 0,1	Central: 0,6	Unknown: 0,0	
% Time in CSR: 0,0			
Total Usage			
Used Days >= 4 hrs : 282	Used Days < 4 hrs : 53	% Used Days >= 4 hrs : 76	
Days not used: 35	Total days: 370	Total hours used: 2003:02	
Median daily usage: 6:25	Average daily usage: 5:24		

Fig. 2 Summary statistics of the CPAP over 2018

Summary Graphs

16.1.2019 - 17.2.2019 Device: AirSense 10 AutoSet (S/N: 23171880780)

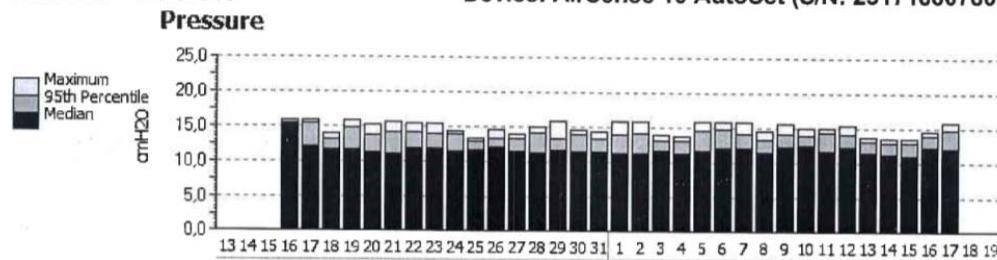


Fig. 3 Summary of pressure over a month

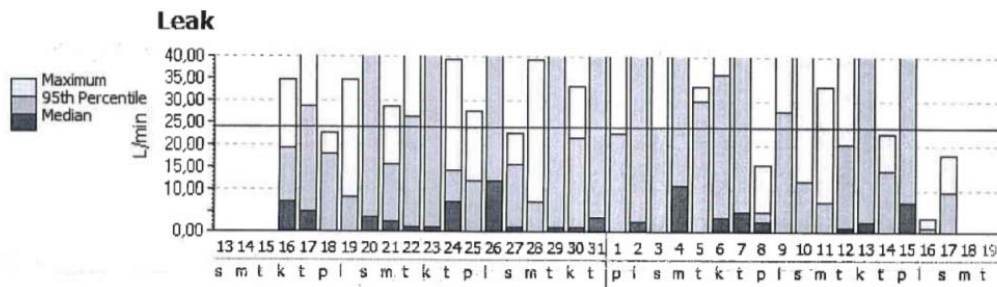


Fig. 4 Summary of leak over a month

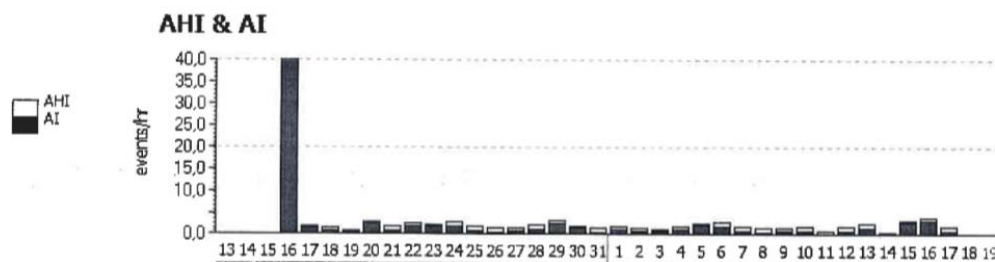


Fig. 5 Summary of AHI & AI over a month

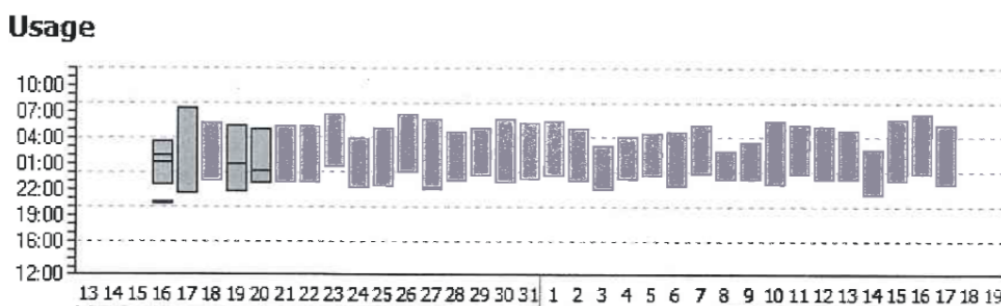


Fig. 6 Summary of usage over a month

IV. DISCUSSION

CPAP-treatment is working technically well, and respiration blocks have not existed in the 2011-2019 treatment and follow-up window. According to sleep clinics, no special apnea rail is necessary, but on the other side, there are no problems in combined simultaneous use. The patient was guided to discuss options again with his dentist, as the responsibility was transferred to the dentist. If the sleep apnea rail is implemented and it helps in the wear of teeth and also helps alleviate apnea, there might rise a need to refit the face mask, might arise or at least refit the tightening belts, which a specialized nurse at the sleep clinic can do.

In the future, if apnea rails are utilized and are sufficient treatment alone, and if the patient wants to test the effectiveness of the rails, a sleep clinic can measure this via night polygraphics. For now, regular CPAP treatment and the follow-up continue at the sleep clinic. Driving health requirements have been fulfilled in terms of the driving license.

Traveling difficulties were not considered at all. However, professional drivers are on the road continuously; therefore, this kind of examination does not help. Lighter systems should be available for persons who travel more. Similarly, persons, who are active hikers, cannot carry heavy CPAP systems with them, resulting in a number of nights in which sleep is not supported by CPAP devices. This way of treatment hinders patients from their active life. There exist many potential technical development possibilities in the treatment of OSA [8].

V. CONCLUSION

There are many situations in which CPAP treatments are difficult to employ, for example, in traveling. Sleep apnea can be connected to bruxism, which is aided by face masks that

press the lower jaw backwards. There are many possibilities for better technical devices that could be developed in this field.

REFERENCES

- [1] F. Green, I. López and M. Simmons, "Obstructive Sleep Apnea Disparity among Truck Drivers: Danger on American Roads", *Florida Public Health Review* Vol. 15, Article 8, 2018, pp. 75-82. Available at: <https://digitalcommons.unf.edu/fphr/vol15/iss1/8>
- [2] American Academy of Sleep Medicine (AASM), *Hidden health crisis costing American billions: Underdiagnosing and undertreating obstructive sleep apnea draining healthcare system, 2016*. Retrieved from <http://aasm.org/resources/pdf/sleepapnea-economic-crisis.pdf>
- [3] National Highway Transportation Safety Administration, *Large trucks: 2014 data*. Traffic Safety Facts. Report No. DOT HS 812 279, May 2016. Washington, DC.
- [4] European Union. Commission Directive 2014/85/EU of 1 July 2014, amending Directive 2006/126/EC of the European Parliament and of the Council on driving licences. *OJ L* 194, 2.7.2014, pp. 10-13.
- [5] W.T. McNicholas (ed), "New Standards and Guidelines for Drivers with Obstructive Sleep Apnoea Syndrome", *Report of the Obstructive Sleep Apnoea Working Group*. Brussels, European Commission, 2013.
- [6] M. R. Bonsignore, W. Randerath, R. Riha, D. Smyth, C. Gratziou, M. Goncalves and W. T. McNicholas, "New rules on driver licensing for patients with obstructive sleep apnoea", *EU Directive 2014/85/EU*, Editorial, *Eur Respir J*, Vol. 47, 2016, pp. 39-41
- [7] A. Dwarakanath, M. Twiddy, D. Ghosh, et al., "Variability in clinicians' opinions regarding fitness to drive in patients with obstructive sleep apnoea syndrome (OSAS)". *Thorax* Vol. 70, 2015, pp. 495-497.
- [8] N. Bitterman, K. Klimovich & G. Pillar, "Home healthcare devices. Challenge of CPAP design for effective home treatment", *The Design Journal*, Vol. 22, sup1, April 2019, pp. 669-681, DOI: 10.1080/14606925.2019.1595446
- [9] A. Bachour, P. Vitikainen, P. Virkkula & P. Maasilta, "CPAP interface: satisfaction and side effects". *Sleep and Breathing*, Vol. 17(2), 2013, pp. 667-672.
- [10] T. E. Weaver, "Don't start celebrating—CPAP adherence remains a problem", *Journal of Clinical Sleep Medicine*, Vol. 9(06), 2013, pp.551-552.
- [11] C. F. Ryan, L. L. Love, D. Peat, J. A. Fleetham, A. A. Lowe, "Mandibular advancement oral appliance therapy for obstructive sleep apnea: eVect on awake calibre of the velopharynx", *Thorax*, Vol. 54, November 1999, pp.972-977.

- [12] W. Schmidt-Nowara, A. Lowe, L. Wiegand, et al., "Oral appliances for the treatment of snoring and obstructive sleep apnea: a review", *Sleep* Vol 18, March 1995, pp. 501–510.
- [13] American Sleep Disorders Association, "Practice parameters for the treatment of snoring and obstructive sleep apnea with oral appliances", *Sleep*, Vol. 18, March 1995, pp. 511–3.
- [14] M. Friedman, J. Ofer, M. S. Hwang, W. F. Bergler, I. Fietze, P. Rombaux, G. B. Mwenge, S. Yalamanchali, J. N. Campana and J. T. Maurer. "Targeted hypoglossal nerve stimulation for the treatment of obstructive sleep apnea: Six-month results", *The Laryngoscope*, Vol. 126, 11 November 2016, pp. 2618-2623.
- [15] B. Tucker Woodson, R. J. Soose, M.B. Gillespie, P. Kingman Strohl, J. T. Maurer, N. de Vries, D. L. Steward, J. Z. Baskin, M. S. Badr, H. Lin, T. A. Padhya, S. Mickelson, W. McDowell Anderson, O. M. Vanderveken, P. J. Strollo, Jr, on Behalf of STAR Trial Investigators, "Three-Year Outcomes of Cranial Nerve Stimulation for Obstructive Sleep Apnea: The STAR Trial", *Otolaryngology–Head and Neck Surgery*, Vol. 154 issue 1, November 2015, pp. 181-188
- [16] V. Bisogni, M. F. Pengo, A. De Vito, G. Maiolino, G. Paolo Rossi, J. Moxham & J. Steier, "Electrical stimulation for the treatment of obstructive sleep apnoea: a review of the evidence", *Expert Review of Respiratory Medicine*, Vol. 11:9, July 2017, pp. 711-720, DOI: 10.1080/17476348.2017.1358619
- [17] The Finnish Medical Society Duodecim, "Sleep apnea (obstructive sleep apnea in adults). Current Care Guidelines. Working group set up by the Finnish Medical Society Duodecim", The Finnish Respiratory Society and Finnish Sleep Research Society. Helsinki. In *The Finnish Medical Society Duodecim*, 2017 (referred May 31, 2019). Available online at: www.kaypahoito.fi
- [18] Anon, "Sleep-related breathing disorders in adults: recommendations for syndrome definition and measurement techniques in clinical research", *Sleep* Vol. 22, August 1999, pp. 667-89.
- [19] Institute for Clinical Systems Improvement (ICSI), *Diagnosis and treatment of obstructive sleep apnea*. Bloomington (MN). March 2005
- [20] L. Agarwal and A. Gupta, "Role of Orthodontist in Obstructive Sleep Apnea - An Orthodontic Review". *Journal of Orthodontics & Endodontics*, Vol. 2, No. 3, August 2016 10, pp. 1-7. <http://orthodontics-endodontics.imedpub.com>.
- [21] H. Avellan-Hietanen, P. Brander, A. Bachour, "Symptoms during CPAP therapy are the major reason for contacting the sleep unit between two routine contacts", *J Clin Sleep Med*. Vol. 15(1), 2019, pp. 47–53.
- [22] S. Garbarino, P. Durando, O. Guglielmi, G. Dini, F. Bersi, S. Fommarino, et al., "Sleep Apnea, Sleep Debt and Daytime Sleepiness Are Independently Associated with Road Accidents. A Cross-Sectional Study on Truck Drivers". *PLoS ONE*, Vol. 11(11), November 2016. e0166262. doi:10.1371/journal.
- [23] Nukute company information www.nukute.com. Read 4 Sept 2019.

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