SLEEP DISORDERED BREATHING

Time course of changes in driving simulator performance with and without treatment in patients with sleep apnoea hypopnoea syndrome

P M Turkington, M Sircar, D Saralaya, M W Elliott

....

See end of article for
authors' affiliations
....

Correspondence to:
Dr P M Turkington,
Department of Respiratory
Medicine, St James's
University Hospital, Beckett
Street, Leeds LS9 7TF, UK;
pete.turkington@
dial.pipex.com

Background: Improvements in driving simulator performance have been demonstrated in patients with sleep apnoea hypopnoea syndrome (SAHS) after several months of treatment, but it is not known how quickly these improvements are achieved and lost. The aim of this study was to assess the time course of changes in driving simulator performance in patients with SAHS following treatment with continuous positive airways pressure (CPAP).

Methods: Eighteen patients with severe SAHS performed a driving simulator test at baseline (before treatment) and at days 1, 3, and 7 of a 2 week CPAP trial period. CPAP was then discontinued and the patients performed three further driving simulator tests after 1, 3, and 7 days. Eighteen patients with severe SAHS acted as controls and performed the driving simulator test on seven occasions in a pattern similar to that of the treated patients.

Results: Significant improvements in tracking error (p = 0.004), reaction time (p = 0.036), and the number of off road events per hour (p = 0.032) were seen in the CPAP treated group compared with the controls at 7 days. Following discontinuation of CPAP for 7 days a significant difference in driving simulator performance persisted between the two groups, but the size of the difference had reduced.

Conclusion: Driving simulator performance in patients with severe SAHS improves within the first few days of starting CPAP and these improvements appear to be sustained for up to 1 week after withdrawal. Further data about the usefulness of driving simulators in predicting safe driving are needed before these results can be used in advising patients on driving. However, the data appear to suggest that driving can be safely resumed after a few days of effective CPAP treatment.

P atients with sleep apnoea hypopnoea syndrome (SAHS) have been shown to be at a significantly greater risk of having a traffic accident than the general population.[1-8] As driving is an essential part of everyday life for most people, physicians treating patients with SAHS have come under increasing pressure to assess their driving ability. Furthermore, there is little evidence to help advise patients when driving can be safely restarted after institution of treatment or whether it is safe to continue driving if treatment is missed for a few nights—for example, when away on business or a short holiday. Assessing an individual's ability to drive is difficult and prediction from physiological and clinical markers of SAHS is poor.[3] Simple computer based driving simulators[9] which measure the ability to track and maintain attention—two key components of driving—have recently been developed. Patients with SAHS have been found to perform poorly on such simulators, comparable to the effect of driving with a blood alcohol concentration above the legal limit.[9-15]

Improvements in driving simulator performance have been reported[13 16 17] following several months of treatment with continuous positive airways pressure (CPAP) in patients with SAHS. However, it is not known how quickly these improvements are obtained and whether they can be translated into safer driving, although several studies have described a reduction in the overall risk of a car crash after institution of treatment with CPAP[18-20] and uvulopalato-pharyngoplasty (UVPPP).[21] Furthermore, recent evidence suggests that there is an association between performance on a driving simulator and the risk of a car crash[22] and, in particular, the number of off road events per hour on a

driving simulator has an independent association with a history of a previous car crash.[23]

The aim of this study was to assess the time course of changes in driving simulator performance in patients with severe SAHS and hypersomnolence, both during a 2 week trial of CPAP and after cessation of CPAP treatment.

METHODS
Subjects
Eighteen patients with moderate to severe SAHS who agreed to participate were recruited to the study when they attended for a 2 week trial of CPAP treatment. Each patient had undergone an in-hospital automatic CPAP titration study (Autoset Clinical 1, ResMed (UK), Abingdon, Oxon) and had been listed for a 2 week CPAP trial. Patients try CPAP for 2 weeks at home and then return it before being reviewed in clinic a few weeks later, when a decision about long term treatment is made; this is routine practice in our laboratory. Eighteen patients recruited from the Sleep Clinic with moderate to severe SAHS (respiratory disturbance index (RDI) >50 events per hour and Epworth score >12) who had also been listed for CPAP acted as controls and performed the driving simulator tests before any CPAP trial. A brief clinical history and examination was obtained on each patient and the Epworth score[24] was recorded.

Written consent was obtained before participation and the study protocol was approved by the local ethics committee.

DRIVING SIMULATION
Each patient performed a 20 minute divided attention driving simulation test (DADS) after a 5 minute practice

session using a commercially available simulator (SimDrive Divided Attention Driving Simulator, Stowood Scientific Instruments, Oxford, UK) at baseline (before CPAP).[17] The object of the test was to steer an image of a car bonnet down the centre of a winding road as accurately as possible (measuring ability to track) using a standard computer game steering wheel (Grandprix 1, Thrustmaster, USA). The test automatically stopped if the car was off the road for more than 15 seconds. During the test single digits, which changed randomly, were displayed at the corner of the screen. To test vigilance and reaction time the subjects were required to identify the number ''2'' when it appeared by pressing a button on the same side of the steering wheel as it appeared on the screen.

The 18 patients who underwent the CPAP trial performed three more 20 minute tests on days 1, 3, and 7 on CPAP. After 2 weeks CPAP was discontinued and the subjects performed three further tests on days 1, 3, and 7 off CPAP. The 18 subjects who acted as controls also performed six further simulator tests in a pattern identical to the CPAP treated patients. All driving simulation tests were performed at the same time of day (18.00 hours was chosen because this was the time that patients attended for their CPAP loan and hence was the time of their first baseline study). All subjects were asked to refrain from drinking coffee for 6 hours and alcohol for 24 hours prior to the tests. Results were expressed as tracking error (standard deviation from the centre of the road), reaction time (average time to respond to target number), and number of off road events per hour

Sleep study and CPAP trial

Limited sleep studies were carried out using either the Autoset Clinical 1 (ResMed (UK), Abingdon, Oxon) or the Densa DMS2000 (Ferraris Medical Ltd, Enfield, UK). The Densa DMS2000 records oronasal airflow (thermistors), oxygen saturation, snoring (microphone), thoracic and abdominal respiratory effort (strain gauges), and heart rate (ECG). The Autoset Clinical 1 detects apnoeas, hypopnoeas, and inspiratory flow limitation through a flow sensor attached to the patient with nasal cannulae. The results were interpreted using standard criteria with the RDI expressed per hour of study. Subjects used the Sullivan V Elite (ResMed (UK), Abingdon, Oxon) for their 2 week CPAP trial at the pressure determined from the titration study.

Analysis of data

Statistical analysis of all data was performed with SPSS version 9.0 for Windows. Patient demographic and sleep study data are expressed as mean (SD). Driving simulator data did not approximate to a normal distribution and were therefore expressed as median and interquartile range (IQR). Comparisons in driving simulator performance between the treated and untreated groups were made using the Mann-Whitney U test. A p value of <0.05 was considered to indicate statistical significance.

RESULTS

A total of 36 patients were recruited to the study; 18 were tested on and off CPAP and 18 acted as controls and performed all their driving simulator tests before CPAP. There were no significant differences in demographic data between patients treated with CPAP and those who acted as controls (table 1). Two patients asked to participate as CPAP treated subjects and seven asked to participate as controls declined consent; however, they did not differ significantly in terms of baseline characteristics from the 36 who gave their consent (RDI 61 v 57; Epworth 16 v 15.5). At baseline the median (IQR) tracking error was 0.294 (0.222–0.481), reaction time was 2.25 (1.84–3.44) s, and number of off road events was 9 (0–33) per hour. There were no significant differences in driving simulator performance between controls and CPAP treated patients at baseline (tracking error (p = 0.606), reaction time (p = 0.389), and off road events (p = 0.719)).

Seven days after CPAP was started driving simulator performance was significantly better in the CPAP treated group than in the controls (tracking error, p = 0.004; reaction time, p = 0.036; off road events per hour, p = 0.032). Seven days after discontinuation of the CPAP trial a statistically significant difference in performance on the simulator between the groups remained, although the size of the effect was smaller (tracking error, p = 0.025; reaction time, p = 0.043; off road events per hour, p = 0.05). The results are shown in figs 1, 2 and 3. There were no changes in driving simulator test results in the control patients over the seven tests, suggesting that any learning effect of repeated tests is minimal.

Subjective measures of hypersomnolence (Stanford sleepiness scale) significantly improved in the treated patients while on CPAP (median (IQR) 3 (2–4) at baseline v 2 (2–3) at day 3 on CPAP, p = 0.004). After discontinuation of CPAP, sleepiness once again deteriorated (3 (2–4) at day 7 of CPAP, p = 0.05). There was no significant change in subjective hypersomnolence in the control group over the study period (3 (2–4) at baseline, p = 0.65).

Compliance with CPAP was assessed with inbuilt clocks on each machine. For the 18 treated patients CPAP was used for a mean (SD) of 4.9 (1.5) hours. Median (IQR) Epworth score improved at the end of the trial period of CPAP from 15.5 (12.75–19) to 6 (2–8.75), p<0.0001.

DISCUSSION

This study shows that driving simulator performance in patients with SAHS improves quickly after starting treatment with CPAP; vigilance, tracking, and the ability to keep the ''car'' on the road all improved during the first 7 days of starting CPAP. Following discontinuation of CPAP, driving simulator performance appeared to be relatively well preserved but was beginning to fall off by day 7.

There are a number of limitations to this study. Firstly, as with all repeated tests of skill, there was the possibility of a ''learning effect'' on the driving simulator. However, all

Table 1 Demographic data of CPAP treated patients and controls

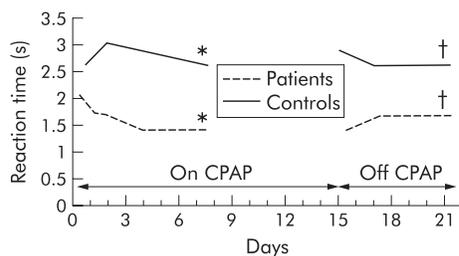|	CPAP treated group	Controls	p value
Age (years)	49.9 (10)	51.7 (12.2)	0.429 (NS)
Sex (% male)†	94%	94%	1.0 (NS)§
BMI (kg/m²)	39 (7.7)	36.6 (5.3)	0.285 (NS)
Neck circumference (cm)	47.3 (3.9)	45 (5.3)	0.147 (NS)
RDI (events/h)	59.8 (16.9)	58.3 (15.7)	0.791 (NS)
RDI on CPAP (events/h)	11.1 (10)	N/A	N/A
Epworth score*	15.5 (12.75–19)	16 (14.75–19.25)	0.662 (NS)‡

CPAP = continuous positive airway pressure; BMI = body mass index; RDI = respiratory disturbance index.
Data are expressed as mean (SD) except *which are expressed as median (IQR) and †expressed as percentage.
Significance tested by t tests except ‡where significance was tested by the Mann-Whitney test and §by χ^2 test.
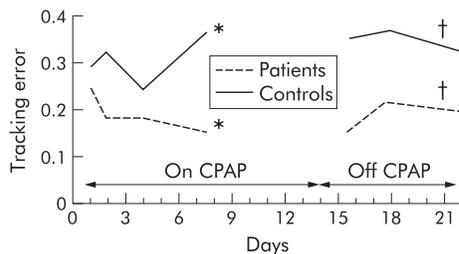
Figure 1 Time plot of tracking error in both CPAP treated patients and controls. Data are expressed as median values. *Significant difference in the median tracking error between the two groups at day 7 while treated group on CPAP (Mann-Whitney U tests). †The significant difference between the two groups persisted after CPAP was discontinued for 7 days in the treated group (Mann-Whitney U test).

patients underwent a 5 minute practice session at baseline to accustom them to the use of the simulator. One study[10] has suggested that at least three 5 minute practice runs are required to abolish any learning effect on a similar simulator, but a further study found no significant learning effect after 5 minutes on a simulator slightly different from the one used in this study (subjects were asked to keep a cross in a box rather than to steer along a road).[9] The fact that our control patients, who were not treated with CPAP but performed the simulator test at similar intervals as the treated patients, did not demonstrate any significant changes in their ability suggests that any learning effect was minimal. Secondly, our study population was a selected population of patients with severe SAHS and marked hypersomnolence and therefore these observations cannot be generalised to all patients attending a sleep clinic who, on average, will have milder disease.

Limited sleep studies using either the Densa DMS2000 or the Autoset Clinical 1 were used to establish the diagnosis of obstructive sleep apnoea (OSA) and assess its severity (RDI). Studies have shown the sensitivity and specificity of the Densa DMS2000 to be 82% and 90% for the diagnosis of OSA[25] and of the Autoset to be 100% and 92%[26]; however, both machines underscored hypopnoeas when compared with full polysomnography. We may therefore have underestimated the severity of OSA in terms of RDI in this study. Furthermore, a recent meta-analysis of diagnostic tools in sleep apnoea failed to recommend standardisation of methodology[27] and limited studies appeared to be most useful when investigating OSA. A further study by Douglas et al[28] concluded that recording sleep was of no diagnostic value and that OSA could be defined as accurately using RDI as expressed as time in bed as RDI expressed as time asleep.

Figure 2 Time plot of reaction time in both CPAP treated patients and controls. Data are expressed as median values. *Significant difference in the median reaction time between the two groups at day 7 while treated group on CPAP (Mann-Whitney U tests). †The significant difference between the two groups persisted after CPAP was discontinued for 7 days in the treated group (Mann-Whitney U test).
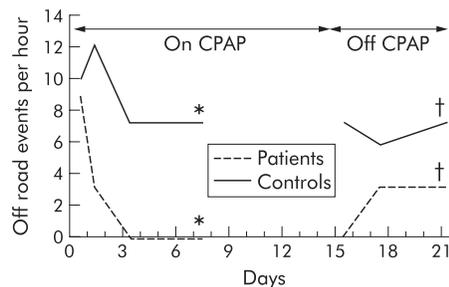
Figure 3 Time plot of off road events per hour in both CPAP treated patients and controls. Data are expressed as median values. *Significant difference in the median off road events per hour between the two groups at day 7 while treated group on CPAP (Mann-Whitney U tests). †The significant difference between the two groups persisted after CPAP was discontinued for 7 days in the treated group (Mann-Whitney U test).

The results of this study compare favourably with a previous study by Lamphere et al[29] which showed that objective sleepiness improved in SAHS patients after just one night of treatment with CPAP. The improvement continued over time but appeared to plateau at 14 nights; the authors argued that this implied that patients with SAHS suffer from a chronic functional sleep loss from which it takes several nights of CPAP to recover. In our study, although significant improvements in driving simulator performance were seen after one night of CPAP, the improvements appeared to continue until day 7. A further study by Kribbs et al[30] showed that CPAP improved both subjective and objective sleepiness and psychomotor vigilance after 30–237 days in 15 patients with SAHS. However, all of these improvements were lost if the CPAP was withdrawn for just one night. Our study did not demonstrate such a rapid return of sleepiness, although we did not measure objective sleepiness with multiple sleep latency tests and poor psychomotor performance. We did see a return of subjective sleepiness but this took 7 days to become statistically significant; this difference may be explained in part by the small numbers of patients in each study. There was a trend toward deterioration in psychomotor performance in our study which did not reach statistical significance by day 7; however, our patients were using a divided attention driving simulator test (DADS) compared with the psychomotor vigilance test (PVT) used in the study by Kribbs et al.

A number of studies have shown a reduction in car accidents in patients with SAHS successfully treated with CPAP. Findley et al[19] showed that SAHS patients using CPAP regularly had a lower rate of car accidents than those not using CPAP (p<0.02). Krieger et al,[18] in a study of 547 SAHS patients, found that the average number of accidents (p<0.01) and near miss collisions (p<0.01) was reduced following treatment with CPAP. George[31] showed that, after 3 years of treatment with CPAP, the rate of car accidents fell significantly in 210 SAHS patients compared with the 3 years before the CPAP was instituted. Furthermore, the accident rate remained high over the time period in 27 patients with SAHS who were unable to tolerate CPAP, a pattern of results similar to the driving simulator performance data in our study.

Others have also shown improvements in simulator performance following treatment of SAHS. Hack et al[17] demonstrated improvements after 1 month of CPAP compared with placebo treated controls, and Haraldsson et al[32] found improvements using a complex simulator following treatment with UVPPP. The magnitude of changes was similar to those found in our study. It is not certain, however, how performance on a simple driving simulator reflects "on

road'' driving ability. The fact that driving simulator performance improves and the number of adverse driving events is reduced after treatment of SAHS does not mean that the two are linked and that data derived from the driving simulator can be relied upon in making judgements about a patient's ability to drive. However, there is emerging evidence to suggest a link between driving simulator ability and risk of a car crash. Findley et al have presented work, as yet only published in abstract form,[22] showing that SAHS patients with a history of a car crash had a higher rate of poor performance on a driving simulator than those without a prior crash. We have also shown in a further study of 120 patients that the number of off road events per hour on a driving simulator has an independent association with a previous car crash.[23]

Further studies are needed but, if simulator data are shown to be useful predictors of on road driving ability, then our data show that improvement is seen rapidly after starting treatment and is not lost even after a few days without treatment. Once patients are established on treatment, driving can probably be safely resumed after a few days.

. . . .

Authors' affiliations
P M Turkington, M Sircar, D Saralaya, M W Elliott, Department of Respiratory Medicine, St James's University Hospital, Leeds LS9 7TF, UK

REFERENCES
1 **Young T**, Blustering J, Finn L, et al. Sleep-disordered breathing and motor vehicle accidents in a population-based sample of employed adults. Sleep 1997;**20**:608–13.
2 **George CF**, Smiley A. Sleep apnea and automobile crashes. Sleep 1999;**22**:790–5.
3 **Barbe F**, Pericas J, Munoz A, et al. Automobile accidents in patients with sleep apnea syndrome. An epidemiological and mechanistic study. Am J Respir Crit Care Med 1998;**158**:18–22.
4 **Teran-Santos J**, Jimenez-Gomez A, Cordero-Guevara J. The association between sleep apnoea and the risk of traffic accidents. N Engl J Med 1999;**340**:847–51.
5 **Ohayon MM**, Guilleminault C, Priest RG, et al. Snoring and breathing pauses during sleep; telephone interview survey of a United Kingdom population sample. BMJ 1997;**314**:860–3.
6 **Findley LJ**, Unverzagt ME, Suratt PM. Automobile accidents involving patients with obstructive sleep apnea. Am Rev Respir Dis 1988;**138**:337–40.
7 **Noda A**, Yagi T, Yokota M, et al. Daytime sleepiness and automobile accidents in patients with obstructive sleep apnea syndrome. Psychiatry Clin Neurosci 1998;**52**:221–2.
8 **Horstmann S**, Hess CW, Bassetti C, et al. Sleepiness-related accidents in sleep apnea patients. Sleep 2000;**23**:383–9.
9 **George CFP**, Boudreau AC, Smiley. Simulated driving performance in patients with obstructive sleep apnoea. Am J Respir Crit Care Med 1996;**154**:175–81.
10 **Juniper M**, Hack MA, George CF, et al. Steering simulation performance in patients with obstructive sleep apnoea and matched control subjects. Eur Respir J 2000;**15**:590–5.
11 **Findley L**, Unverzagt M, Guchu R, et al. Vigilance and automobile accidents in patients with sleep apnea or narcolepsy. Chest 1995;**108**:619–24.
12 **George CF**, Boudreau AC, Smiley A. Comparison of simulated driving performance in narcolepsy and sleep apnea patients. Sleep 1996;**19**:711–7.
13 **Findley LJ**, Fabrizio MJ, Knight H, et al. Driving simulator performance in patients with sleep apnea. Am Rev Respir Dis 1989;**140**:529–30.
14 **Findley LJ**, Suratt PM, Dinges DF. Time-on-task decrements in ''steer clear'' performance of patients with sleep apnea and narcolepsy. Sleep 1999;**22**:804–9.
15 **Risser M**, Ware JC, Freeman F. Driving simulation with EEG monitoring in normal and obstructive sleep apnoea patients. Thorax 2000;**23**:393–8.
16 **George CFP**, Boudreau AC, Smiley A. Effects of nasal CPAP on simulated driving performance in patients with obstructive sleep apnoea. Thorax 1997;**52**:648–53.
17 **Hack M**, Davies RJ, Mullins R, et al. Randomised prospective parallel trial of therapeutic versus subtherapeutic nasal continuous positive airway pressure on simulated steering performance in patients with obstructive sleep apnoea. Thorax 2000;**55**:224–31.
18 **Krieger J**, Meslier N, Lebrun T, et al. Accidents in obstructive sleep apnea patients treated with nasal continuous positive airway pressure: a prospective study. The Working Group ANTADIR, Paris and CRESGE, Lille, France. Association Nationale de Traitement à Domicile des Insuffisants Respiratoires. Chest 1997;**112**:1561–6.
19 **Findley L**, Smith C, Hooper J, et al. Treatment with nasal CPAP decreases automobile accidents in patients with sleep apnea. Am J Respir Crit Care Med 2000;**161**:857–9.
20 **Cassel W**, Ploch T, Becker C, et al. Risk of traffic accidents in patients with sleep-disordered breathing: reduction with nasal CPAP. Eur Respir J 1996;**9**:2606–11.
21 **Haraldsson PO**, Carenfelt C, Lysdahl M, et al. Does uvulopalatopharyngoplasty inhibit automobile accidents? Laryngoscope 1995;**105**:657–61.
22 **Findley LJ**, Smith C, Harvey K. Driving simulator performance is poor in patients with sleep apnoea who have had an automobile crash. Am J Respir Crit Care Med 2000;**16**:A772.
23 **Turkington PM**, Sircar M, Allgar V, et al. Relationship between obstructive sleep apnoea, driving simulator performance, and risk of road traffic accidents. Thorax 2001;**56**:800–5.
24 **Johns MW**. A new method for measuring daytime sleepiness: the Epworth sleepiness scale. Sleep 1991;**14**:540–5.
25 **Lloberes P**, Montserrat JM, Ascaso A, et al. Comparison of partially attended night time respiratory recordings and full polysomnography in patients with suspected sleep apnoea/hypopnoea syndrome. Thorax 1996;**51**:1043–7.
26 **Bradley PA**, Mortimore IL, Douglas NJ. Comparison of polysomnography with ResCare Autoset in the diagnosis of the sleep apnoea/hypopnoea syndrome. Thorax 1995;**50**:1201–3.
27 **Ross SD**, Sheinhait IA, Harrison KJ, et al. Systematic review and meta-analysis of the literature regarding the diagnosis of sleep apnea. Sleep 2000;**23**:519–32.
28 **Douglas NJ**, Thomas S, Jan MA. Clinical value of polysomnography. Lancet 1992;**339**:347–50.
29 **Lamphere J**, Roehrs T, Wittig R, et al. Recovery of alertness after CPAP in apnea. Chest 1989;**96**:1364–7.
30 **Kribbs NB**, Pack AI, Kline LR, et al. Effects of one night without nasal CPAP treatment on sleep and sleepiness in patients with obstructive sleep apnea. Am Rev Respir Dis 1993;**147**:1162–8.
31 **George CF**. Reduction in motor vehicle collisions following treatment of sleep apnoea with nasal CPAP. Thorax 2001;**56**:508–12.
32 **Haraldsson PO**, Carenfelt C, Lysdahl M, et al. Long-term effect of uvulopalatopharyngoplasty on driving performance. Arch Otolaryngol Head Neck Surg 1995;**121**:90–4.