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# Driving and Automobile Crashes in Patients with Obstructive Sleep Apnoea/Hypopnoea Syndrome

*C F P George*
*Department of Medicine, University of Western Ontario, London Health Sciences Centre - Victoria Campus, 375 South Street, London, ON, Canada N6A 4G5*
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## Abstract

Driving is a complex task involving distinct cognitive, perceptual, motor, and decision making skills. After placing the vehicle on the road, the driver must constantly survey the ever changing roadway environment to keep the vehicle in the lane and moving at an appropriate safe speed. This surveillance involves two distinct visual tasks: estimating and responding to the oncoming curvature and controlling lane position. Driving is therefore a divided attention task involving speed and lane control as well as monitoring. To do this in a safe manner requires careful attention and alertness which can be problematic for patients with obstructive sleep apnoea/hypopnoea syndrome (OSAHS) or other sleep disorders.

Human error is a major determinant in automobile crashes with inattention, improper lookout, and other perceptual and cognitive errors accounting for up to 40% of such mishaps.[1,2] Sleepiness can lead to increased inattention and, not surprisingly, performance is often diminished in sleepy patients. The effects of sleepiness on various aspects of performance have been well documented. Indeed, depending on the task at hand, performance degradation due to sleepiness may be the same as, or greater than, that due to alcohol.[3,4] As a result, driver sleepiness is widely believed to be an important cause of road traffic injuries. Published estimates of the proportion of crashes attributable to sleepiness vary more than tenfold, from 1–3% in the US[5] to 10% in France and over 30% in Australia.[6] The US National Highway Traffic Safety Administration (NHTSA) estimates that drowsiness is the primary causal factor in 100 000 police reported crashes each year, resulting in 76 000 injuries and 1500 deaths. These numbers represent 1–3% of all police reported crashes and 4% of fatalities.[5,7] Other sources have reported higher estimates. One UK study[8] concluded that 16–20% of motor vehicle crashes were sleep related based on police reported data, while another[9] arrived at a figure of 9–10% based on drivers' self-reports. While this variation reflects the quality of the data available, there is little doubt that drowsy drivers are involved in many motor vehicle crashes and motor vehicle injury accounts for a huge burden of death and disability. NHTSA estimates these crashes represent $12.5 billion in monetary losses each year.

The wide variation in estimates of sleep related crashes is due in part to the difficulty in determining the contribution of drowsiness to crash occurrence. In addition to "falling asleep at the wheel", drowsiness contributes to crashes by making drivers less attentive and by impairing performance levels. In other words, subjects do not have to fall asleep to have an accident. However, there is no objective field measure of sleepiness/fatigue which can be used to determine clearly if the crash is due to sleepiness. "Fall asleep crashes", however, have typical characteristics including:

- the problem occurs during late night/early morning or mid afternoon;
- the crash is likely to be serious;
- a single vehicle leaves the roadway;
- the crash occurs on a high speed road;
- the driver does not attempt to avoid a crash;
- the driver is alone in the vehicle.

Sleepiness has both homeostatic and circadian influences with the latter increasing sleep propensity at certain times of the day. Increasing sleepiness of a circadian nature is expected to produce increased motor vehicle crashes at certain times of the day as shown by recent Italian data (fig 1□).[10]

**Figure 1** Relative risk of motor vehicle accidents by time of day. The increase in risk parallels the time of increased circadian sleepiness. Adapted from Garbarino *et al*.[10]

### Risk Factors for Drowsy Driving

While alcohol and/or obstructive sleep apnoea/**hypopnoea syndrome** (OSAHS) may be responsible for sleepiness while driving, there are many other risk factors for drowsy driving. Some of these are probably much more common than OSAHS as risk factors including sleep deprivation/chronic insufficient sleep or medications which increase sleepiness. Sleep related crashes are most common in young people who tend to stay up late, sleep too little, and drive at night. In a recent North Carolina study 55% of "fall asleep crashes" involved people aged 25 years or younger, mostly men.[11] Shift workers and especially night and/or rotating shift workers often suffer from poor quality of sleep as well as insufficient quantity of sleep. More than 25% of the US labour force performs some sort of shift work, particularly commercial vehicle operators.[12] Frequent business travellers—particularly those who drive through the night, in the early afternoon, or at other times when they are normally asleep—are at great risk. Driving alone or driving for long distances without rest breaks increases the risk of drowsy driving. It is important to recognise that these risk factors are not mutually exclusive. The sleep deprived business traveller with OSAHS is not an uncommon situation and the existence of two or more risk factors may synergistically increase the risk for drowsy driving and motor vehicle crashes.[13,14]

### Motor Vehicle Collisions/Crashes in Patients with OSAHS

The first reports of motor vehicle crashes involving patients with OSAHS occurred in 1987.[15,16] Since then, numerous studies have suggested similar results using both subjective (self-report)[17–29] and objective (Department of Motor Vehicles) records.[30–33] Despite these multiple studies, the results have been criticised on epidemiological grounds.[34] Almost all studies have been cross sectional in nature with only one being case controlled;[32] there have been no prospective cohort studies to date. Several of the studies are subject to selection bias because they involve clinic patients. Information bias is also a concern because of a lack of similar information in the control groups. The confounding effects of age, sex, driving exposure, alcohol, and drug use were not adequately considered in most studies. Despite these limitations, most of the evidence continues to suggest that OSAHS confers an increased risk for driving.

These results are biologically plausible since patients with OSAHS are sleepy and inattentive, with reduced reaction times on reaction time testing which can lead to mistakes or mishaps while driving. As a result, many jurisdictions continue to require physician reporting to their local Department of Motor Vehicles regarding sleep disorders and fitness to drive.[35] Recent studies add further, if indirect, support to the hypothesis that patients with OSAHS have increased motor vehicle crashes. Data using both self-report[24,36] and objective records[37,38] indicate that treatment with continuous positive airway pressure (CPAP) markedly reduces the collision/crash frequency.

While the odds ratio for an automobile crash varies widely in the published literature (table 1) and while the crash rate is 2–4 times greater than in the population at large, the actual rate of crashes is still not that high. Many subjects seem never to have a crash. This should not be surprising since motor vehicle crashes are multifactorial in nature with sleepiness playing only a variable part. However, it is important to recognise the retrospective nature of the published data; ideally, physicians dealing with the issue of fitness to drive in patients with OSAHS need prospective data. If more than 65% of patients with OSAHS do not or will not have a crash, predicting the 35% at greatest risk is the current challenge. This has been part of the impetus for the development and testing of driving simulators in patients with OSAHS.

**Table 1**

Motor vehicle crashes in patients with OSAHS

| Study | Clinic patients (Y/N) | No of subjects {dagger} | Odds ratio (95% CI)for MVC | Accident rate (no/driver/year) |
|---|---|---|---|---|
| George[15] | Y | 297 (27) | 10.8 (2.4 to 27.2) | NA |
| Findley[16] | Y | 64 (29) | 7.4 (1.4 to 39.2) | 0.05* |
| Young[30] | N | 913 (221) | 3.4 (1.4 to 8.0) | 0.049* |
| Teran-Santos[32] | Y | 254 (29) | 8.1 (2.4 to 26.5) | NA |
| George[33] | Y | 1163 (582) | 1.9 (1.5 to 2.2) | 0.09 (0.14) |

*Calculated.

{dagger}Number with apnoea/hypopnoea index (AHI) >5 shown in parentheses.

NA = not available; MVC = motor vehicle crash; CI = confidence interval.

## Use of Driving Simulators in OSAHS

With advances in computer technology, various off-road driving simulators have been developed. These are cheaper and obviously safer than in-vehicle or on-road testing, and they allow a greater degree of experimental control and precision of performance measures without the interference of uncontrolled variables that operate in the real world. However, even the most sophisticated driving simulators do not provide all of the visual, vestibular, and proprioceptive changes that occur when turning a steering wheel and the vehicle changes course. Also missing in the laboratory environment is the subject's knowledge that the consequences of driving control responses affect his/her own safety. Most of the driver performance measures and all physiological evidence of driver fatigue can be gathered in either the simulator or in real driving environments. However, some measures such as lane tracking and yaw are more difficult to collect reliably in the open road environment

Many authors have examined the use of a number of simulators to measure driving performance in sleepy subjects. The complexities of these tests vary widely and, although the results have been generally congruent, the difference between sleepy subjects and controls varies considerably.

The Steer Clear, originally promoted as a driving simulator test,[39] is actually a choice reaction test and, while it requires the subject to maintain vigilance (a necessary factor for safe driving), it does not simulate driving. However, patients with OSAHS or narcolepsy have worse performance than control subjects[40] and other studies have confirmed this worse performance on the Steer Clear.[41,42] Although the magnitude of the difference in performance between patients and controls varies widely, none of these studies has shown any correlation between Steer Clear performance and crashes

The Divided Attention Driving Test (DADT) includes a tracking task controlled by a steering wheel and a secondary visual search task.[43] In the DADT the tracking task is a variation of the subcritical tracking task, one of many psychomotor tasks developed to study performance and detect impairment due to fatigue, stress, or drug effects. This task is sensitive to fatigue resulting from hours of work among truck drivers.[44] The DADT was first validated using alcohol and then applied to sleepy patients with OSAHS or narcolepsy. Many, but not all, patients performed much worse than controls and performance in some patients was worse than controls impaired with alcohol. Moreover, performance was seen to improve when OSAHS was successfully treated with nasal CPAP.[45,46]

The Divided Attention Steering Simulation (DASS) involves steering, lane position, and secondary visual search. A computer derived image of the moving edges of a road that winds pseudo-randomly—white on black as in night driving—is presented so that, while driving, the eyes move between the far road in order to estimate the coming curvature and the near road to ensure accurate placement in the lane—two separate processes requiring different skills.[47] Patients with OSAHS perform badly on this simulator compared with matched control subjects,[48,49] and their collision and event rates improve with CPAP.[50]

STISIM is a personal computer (PC) based interactive driving simulator designed to represent a range of psychomotor, divided attention, and cognitive tasks involved in driving.[51] The overall simulation is fully interactive (the driver controls both speed and steering) and includes visual and auditory feedback, a vehicle dynamics model, and ability to modify the driving scenario to measure aspects of driver performance. On this simulator patients with OSAHS performed worse than controls on all performance measures including lane position variability, speed variability, steering rate variability, and crash frequency.[52] Simultaneous EEG measurements revealed increased lapses of attention in OSAHS and these correlated with crash frequency. These data add support to the theory that inattention without overt episodes of falling asleep are all that are needed to produce crashes.

The Swedish Road and Traffic Research Institute driving simulator is an example of an advanced, hi-fidelity, moving base driving simulator. It is mounted in the driver's cabin of a Saab 900[53] and has a moving base system with four degrees of freedom of movement creating the same forces as those normally felt during driving. The system is fully interactive—that is, any action from the driver is fed into the computer which updates the visual presentation and creates the movement of the cabin and the momentum in the steering wheel. Using this sophisticated simulator, patients with sleep apnoea performed much worse than controls while performance improved with successful treatment of OSAHS.[54,55]

Other simulators have assessed driving performance in normal subjects under the influence of alcohol and following sleep restriction to produce sleepiness. Despite the varying complexity of the simulation involved, the results of these off-road simulations are quite consistent in their outcome: driving performance is worse in sleepy subjects regardless of the cause of the sleepiness (disease state or sleep restriction). The magnitude of the decrements in driving performance is similar to that caused by alcohol. However, a more important question remains: can these results be extrapolated to and predict real world, on-road driving? If some patients perform well on the DADT or other simulators, it would stand to reason that some but not all patients with OSAHS will have on-road collisions. The data reviewed previously confirm this—many patients never have collisions. Moreover, when patients are treated (either by CPAP or uvulopalatopharyngoplasty), performance improved on the simulators[46,50,54,55] and, not surprisingly, the actual accident rates returned to normal.[38] The logical extension would therefore be that those who perform poorly on simulators are the ones who have the collisions and that, when they are treated and their simulator performance improves, they are the same patients who account for the reduced collisions. Unfortunately, the data for this final step are not yet available.

## Conclusions

As a group, patients with OSAHS have a higher risk of having motor vehicle crashes. Since the causes of motor vehicle crashes are multifactorial with sleepiness and decreased performance from OSAHS being only one factor, it stands to reason that the increased risk does not apply to all patients; indeed, some never have crashes. Performance on driving simulators is impaired in patients with OSAHS and improves with successful treatment, yet the predictive value of current systems is weak. Fortunately, motor vehicle crash rates return to normal after successful treatment of OSAHS. While research continues in an effort to identify high risk drivers, prompt treatment of OSAHS should remain the priority for the practising clinician.

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