Reducing Motor-Vehicle Collisions, Costs, and Fatalities by Treating Obstructive Sleep Apnea Syndrome

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Study Objectives: Drivers suffering from obstructive sleep apnea syndrome (OSAS) have an increased risk for being involved in motor-vehicle collisions. This study estimates, for the first time, the annual OSAS-related collisions, costs, and fatalities in the United States and performs a cost-benefit analysis of treating drivers suffering from OSAS with continuous positive airway pressure (CPAP).

Design: The MEDLINE-PubMed database (1980 to 2003) was searched for information on OSAS. A meta-analysis was performed of studies investigating the relationship between collisions and OSAS. Data from the National Safety Council were used to estimate OSAS-related collisions, costs, and fatalities and their reduction with treatment. Next, the annual cost of treating OSAS with CPAP was calculated. Finally, multiple 1-way sensitivity analyses were performed.

Setting: N/A.

Patients or Participants: N/A.

Interventions: N/A.

Measurements and Results: More than 800,000 drivers were involved in OSAS-related motor-vehicle collisions in the year 2000. These collisions cost $15.9 billion and 1,400 lives in the year 2000. In the United States, treating all drivers suffering from OSAS with CPAP would cost $3.18 billion, save $11.1 billion in collision costs, and save 980 lives annually.

Conclusion: Annually, a small but significant portion of motor-vehicle collisions, costs, and deaths are related to OSAS. With CPAP treatment, most of these collisions, costs, and deaths can be prevented. Treatment of OSAS benefits both the patient and the public.

Key Words: Sleep, collisions, accidents, motor vehicle, apnea, economics

Abbreviations: OSAS, Obstructive Sleep Apnea Syndrome; OSA, Obstructive Sleep Apnea; CPAP, Continuous Positive Airway Pressure; OR, Odds Ratio; ARP, Attributable Risk Percentage; CI, Confidence Interval; AHI, Apnea-Hypopnea Index

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INTRODUCTION

ACCIDENTS ARE THE FIFTH LEADING CAUSE OF DEATH IN THE UNITED STATES, WITH MORE THAN 97,000 DEATHS PER YEAR.[1] These deaths each year account for more than 2.0 million years of life lost before the age of 65 years.[2] By contrast, heart disease accounts for 1.4 million years of potential life lost annually, and homicides for 0.9 million.

Obstructive sleep apnea syndrome (OSAS), a common problem,[3,4] is now recognized as a risk factor for motor-vehicle collisions (here after referred to as "collisions") and causes sleep fragmentation, nocturnal hypoxia, and hypersomnia, which impairs daytime functioning and driving performance.[5-9] As a result, drivers with OSAS have a higher rate of collisions than do control subjects.[10-19] Studies comparing alcohol-impaired subjects to subjects with untreated OSAS show that subjects with untreated OSAS perform as poorly on simulated steering and psychomotor reaction time tests as legally intoxicated control subjects.[6,20,21]

This study has 2 goals: (1) estimate the number of annual OSAS-related collisions, the costs, and the fatalities in the United States and (2) perform a cost-benefit analysis of treating drivers with OSAS with continuous positive airway pressure (CPAP).

Disclosure Statement

Supported by a $2,000 summer education stipend from ResMed Corporation to Dr. Sassani during medical school. No other research funds were used for this study. Terence M. Davidson, MD, is a member of Medical Advisory Boards for ResMed and Restore Medical.

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METHODS

We searched MEDLINE-PubMed for articles published between 1980 and September 2003. Using keywords "Obstructive Sleep Apnea" and "Sleep Disordered Breathing" 5,133 and 9,915 articles were retrieved, respectively. Search words "accidents," "collisions," and "economics" were then added, but no new articles were retrieved. After scanning nearly 10,000 titles, abstracts of peer-reviewed articles discussing sleep and related collisions were selected for further review. Subsequently, citations referenced in the selected articles were evaluated for selection. Articles focused on pathophysiology were excluded, as were non-English articles. The criteria for inclusion were original research regarding OSAS and collisions, prevalence of OSAS, and management costs and patient compliance.

We obtained data on economic losses and quantified lost quality of life, which together form the comprehensive cost, from the National Safety Council[1] for the year 2000. The National Safety Council's estimates on lost quality of life are based on work by Ted Miller of National Public Services Research Institute.[22,23]

Economic losses include 5 components: (1) wages and productivity losses, (2) medical expenses, (3) administrative expenses, (4) motor-vehicle damage, and (5) employer costs for crashes to workers (See Table 1). For fatalities, the human capital method was used to compute present value of after-tax wages, fringe benefits, and household production.[1] Lost quality of life is the difference between the value of a statistical fatality or injury and the value of after-tax wages, fringe benefits, and household production. In simpler terms, valuation of lost quality of life is what society is willing to pay to prevent death and injuries.[1]

We estimated OSAS-related collision costs, collisions, and fatalities, and a potential reduction in them with CPAP treatment. By calculating

and applying the attributable risk percentage (ARP) of drivers with OSAS to the motor-vehicle collision comprehensive costs, we determined the OSAS-related collision costs. ARP estimates the percentage of all collisions, above and beyond the baseline level of collisions expected regardless of OSAS. ARP, as used in this study, is based on the Levin formula and may also be recognized as the population attributable fraction. Odds ratio (OR) was used instead of the relative risk and, in the following formula, P represents the prevalence rate of OSAS.[24] To calculate the ARP, a meta-analysis was performed to obtain a pooled OR.

$$ARP = [P \times (OR-1) / (P \times (OR-1)+1)] \times 100\% \quad \text{(equation 1)}$$

Several assumptions were made; including (1) the number of drivers with OSAS below the age of 25 years was negligible. (2) The prevalence of OSAS was estimated at 3% based on the Young et al 1993 study[4] of 602 men and women between ages 30 and 60. (3) The cost per collision across all ages matched the distribution of collision rates across all ages. Collision costs for all ages were multiplied by 74% to obtain the collision cost for drivers 25 and older, since 74% of all collisions involve drivers 25 and older.[1] (4) Moreover, "collision" as used in this article refers to "driver" involved in an accident.

After the ARP was used to estimate OSAS-related collision costs, it was also applied to the total number of collisions and fatalities, to estimate the number of collisions and fatalities attributable to OSAS. Finally, reduction in collision costs, collisions, and fatalities were calculated based on an estimated rate of CPAP effectiveness and patient compliance of 70%.[25,26]

Chervin et al's[27] estimates for OSAS diagnosis and treatment were used to estimate annual cost of treatment (polysomnography, $1190; CPAP titration, $1190; CPAP equipment, $1290; initial office visit, $210; annual visit, $70). An extra $250 per year, not included in Chervin et al's analysis, was added for maintenance and replacement parts. Personal communication with several CPAP manufactures and sleep clinic personnel was used to conservatively estimate the useful life of a CPAP machine at 5 years. Our cost estimate assumed only 1 of 5 subjects screened for OSAS actually had sleep apnea and went on to CPAP titration. Once the cost of diagnosis and treatment was estimated for the average driver, it was multiplied by the number of drivers with OSAS. Cost of treatment was then annualized for a cost-benefit analysis.

As a final step, 1-way sensitivity analyses were performed for 5 variables to test how different odds ratios, compliance rates, collision costs, number of drivers screened, and prevalence rates impact the results.

RESULTS

The National Safety Council estimated that the comprehensive accident costs (motor vehicle, work, home, and public accidents) in the year 2000 were more than $1.67 trillion,[1] of which $492.1 billion were attributed to motor-vehicle collisions. Of this amount, $201.5 billion were economic costs.[1] Lost quality of life related to motor-vehicle collisions was estimated at $290.6 billion for the year 2000, (Personal communication with Alan Hoskin, Manager, Research and Statistics Department, National Safety Council). Pooled OR by inverse variance method was 2.52 (95% confidence interval [CI], 1.83 - 3.45) when combined as fixed effects, and 3.25 (95% CI, 1.89 - 5.60) as random effects. The lower 2.52 OR was used in our analysis.

Table 1—Motor-Vehicle Collision Costs for Year 2000

		Cost, in billions $
Economic Costs*		201.5
Wages and productivity loss	71.5	
Medical expenses	24.6	
Administrative expenses	48.0	
Motor vehicle damage	55.5	
Employer costs	1.9	
Lost Quality of Life†		290.6
Comprehensive Costs†		492.1
Fatal motor-vehicle collisions		138.0
Injury, nonfatal motor-vehicle collisions		299.2
Property damage only motor-vehicle collisions		54.9
Comprehensive costs†		492.1

Source: *National Safety Council, Injury Facts, 2001; †National Safety Council – personal communication with NSC Research and Statistics Department.

Of the articles reviewed, we selected all those regarding risk of collisions among patients determined to have OSAS. Several studies were excluded from the meta-analysis because they did not compare collision rates of drivers with OSAS to drivers without OSAS. These excluded studies included 6 studies that used computer software or reaction-time devices to predict driving performance,[6-9,21,28] 1 study was a series of case reports,[29] Three studies analyzed pre-CPAP and post-CPAP driving records,[14,15,26] and 1 was a review of other articles.[30] One study[11] was excluded because tabular data comparing collision rates of patients and controls could not be constructed from the paper. Six studies[10,16-18,31,32] were selected for the meta-analysis, and a Q statistic was derived to test the homogeneity of tabular data. Based on this Q statistic test, combined ORs were performed by inverse variance method (taking study selection to be either a fixed or a random effect and using the software Comprehensive Meta-Analysis v. 1.0.23. (Biostat, Englewood, NJ). Six articles included in the meta-analysis, ranged from 9 months to 5 years in duration. The *P* value associated with Q statistic for heterogeneity was .071, and we judged these studies to be only marginally different from one another. This heterogeneity seems to be due to 2 studies[16,32] with particularly low ORs, which may be attributed to random error. These studies were included in the analysis (Figure 1).

The motor-vehicle collision cost of $492.1 billion was multiplied by 74%, yielding $364.2 billion as the collision cost for drivers 25 and older. The prevalence rate of OSAS of 3%,[4] and an OR of 2.52, obtained from the meta-analysis, yielded an ARP of 4.36%. The ARP multiplied by $364.2 billion (74% of $492.1 billion) yielded an estimated OSAS-related collision cost of $15.9 billion annually. Based on 70% effectiveness treatment with CPAP, collision costs would be reduced annually by $11.1 billion.

Similarly, the ARP was also used to estimate the OSAS-related collisions and fatalities. Total number of collisions and fatalities in the 25 and older group was multiplied by the 4.36% to estimate annual OSAS-related collisions at 810,000 and fatalities at 1,400. Based on 70% CPAP effectiveness, treatment can annually prevent an estimated 567,000 collisions and 980 fatalities in the United States.

Chervin et al's[27] estimates for OSAS diagnosis and treatment with CPAP were used. An extra $250 per year was added for maintenance and replacement parts. There are 163 million drivers 25 or older.[1] With a 3% prevalence rate, more than 4.7 million drivers suffer from OSAS. Annual treatment expenditure of such patients is estimated at $3.18 billion. This amount includes screening costs of those without OSAS (in our analysis, of 5 drivers undergoing a complete sleep study, only 1 is diagnosed with sleep apnea). Thus treatment of all patients with OSAS with CPAP would yield a net annual savings of $7.9 billion in reduced collision costs.

One-way sensitivity analyses (Figures 2-6) test the results based on different ORs, compliance rates, collision costs, number of drivers screened, and prevalence rates. Figures 2, 3, and 6 contain mixed types of data with a primary ($) and a secondary (lives) y-axis. The slope of the primary data series ($) is only dependent on the primary y-axis range of scale. Conversely, slop of the secondary data series (lives) can be increased or decreased based on the selected secondary y-axis range independent of primary y-axis range. At an OR of 1.42, the net savings is approximately zero. Figure 6 tests the various costs and savings based on different diagnosis-to-screen ratios, from 50% of screened diagnosed, to 10% of screened diagnosed with OSAS.

DISCUSSION

Previous Studies

Drivers with OSAS may be poor drivers with higher collision rates. In 1987, George and colleagues[12] presented data in a letter to the editor suggesting that OSAS patients are at an increased risk for collisions. Since

then, numerous studies have shown that drivers with OSAS perform worse on driving simulators,[5,6,8,9,20] have higher collision rates[10,11,13,14,16-19,26,31,32] than controls, and have fewer collisions after treatment with CPAP.[14,15,26,32] A recent study of 1,391 commercial truck drivers found that 28% had OSAS, with more than one third (10.5%) characterized as moderate to severe.[33] This study did find performance impairment in the drivers with OSAS, though the study did not compare collision rates between drivers with and without OSAS.

Several studies have shown increased medical costs of untreated subjects with OSAS.[34,35] In 2001, Findley and Suratt estimated a net savings of $1 million when treating 500 drivers with OSAS for 3 years.[36] In a letter to the editor, Douglas and George estimated a savings of £4 million in the United Kingdom when treating 500 patients with OSAS for 5 years.[37] Our study is the first to estimate the annual OSAS-related collision costs, number of collisions, and fatalities and their reduction with CPAP treatment.

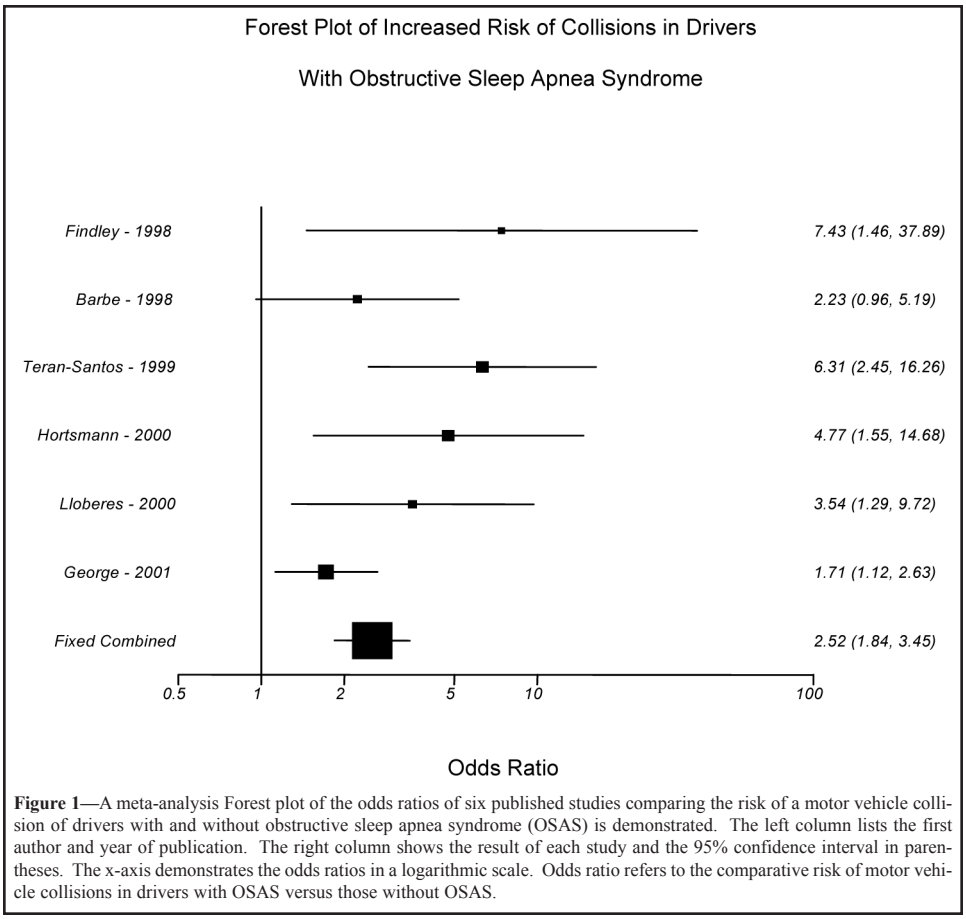

Figure 1—A meta-analysis Forest plot of the odds ratios of six published studies comparing the risk of a motor vehicle collision of drivers with and without obstructive sleep apnea syndrome (OSAS) is demonstrated. The left column lists the first author and year of publication. The right column shows the result of each study and the 95% confidence interval in parentheses. The x-axis demonstrates the odds ratios in a logarithmic scale. Odds ratio refers to the comparative risk of motor vehicle collisions in drivers with OSAS versus those without OSAS.

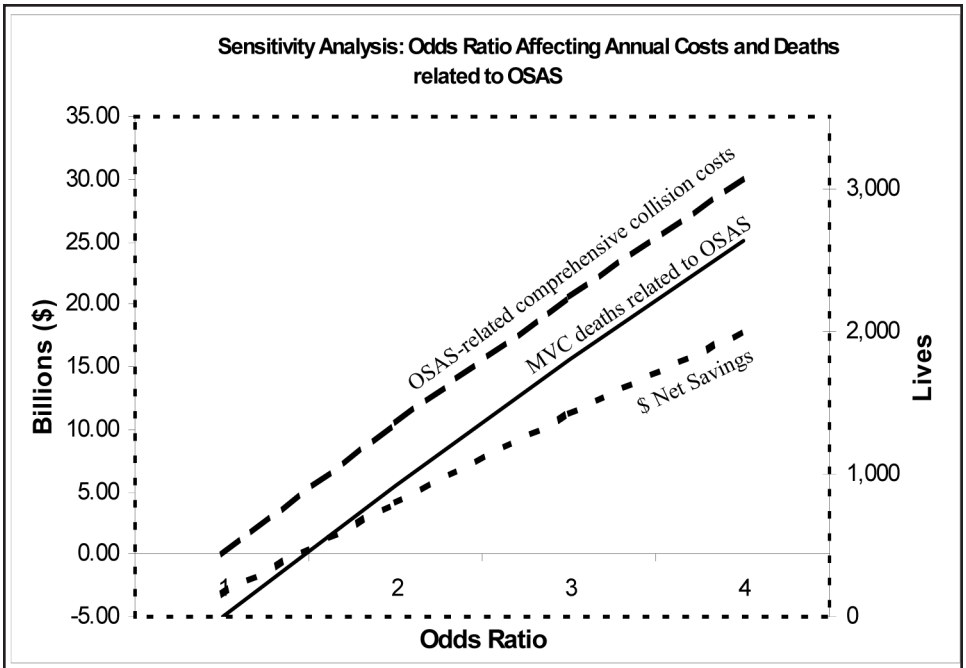

Figure 2—This sensitivity analysis graph illustrates the relationship between the odds ratio of collision risk of drivers with obstructive sleep apnea syndrome (OSAS) and the annual associated collision costs, related deaths, and net savings (reduced costs of collisions - cost of treatment). As the odds ratio increases, the annual collision costs, deaths, and net savings also increase. Odds ratio refers to the comparative risk of motor vehicle collisions in drivers with OSAS versus those without OSAS.

Further Support

As yet another measure to validate the results of our study, we examined data gathered by George[32] to estimate the number of collisions, collision costs, and the number of fatalities when treating OSAS patients with CPAP. The number of collisions per driver per year in drivers with untreated OSAS, 0.18, was subtracted from those of drivers treated with CPAP, 0.06. The difference, 0.12, was deemed to be the number of collisions prevented per driver per year in OSAS subjects treated with CPAP. This value was multiplied by 4.7 million, number of all drivers with OSAS, to obtain 566,000, the annual number of collisions prevented by using CPAP to treat all drivers with OSAS. Next, the number of collisions prevented was converted to a percentage of all collisions. This percentage was multiplied by the comprehensive collision costs and associated fatalities for the year 2000, thus estimating the reduction in collision costs at $11.1 billion and the number of lives saved at 970, if all drivers with OSAS were treated with CPAP. In George's study though, data are presented from those subjected who were not lost to follow up. The actual compliance rate within this group is not reported. If the compliance rate is significantly different from 70%, a correction factor may be used for comparison purposes.

Assumptions and Estimates

Throughout this study all estimates and assumptions were made in an attempt to yield conservative estimates of OSAS-related collision costs, collisions, and fatalities. Liberal estimates of the cost of OSAS diagnosis and treatment were made to further reduce the risk of overstating the benefits of treatment. The average workforce population prevalence of OSAS of 3% (2% women, 4% men) is directly applied to the population of drivers. This may lead to an understatement of results. In the year 2000, approximately 46,000 men drivers were involved in fatal accidents compared to 16,000 women drivers.[1] Some believe that sleep-related collisions are generally more severe and cause greater monetary and life casualty than do other collisions. For the year 2000, death rates per 100,000,000 vehicles miles were 2.86 for night and 1.18 for day.[1] Yet, no *day* versus *night* distinction was made in this analysis to reduce the risk of overstating the results.

During the meta-analysis, two pooled ORs (2.52 vs. 3.25) were obtained. The more conservative pooled OR was used to calculate the ARP. The prevalence of OSAS[38] was used instead of obstructive sleep apnea. To meet OSAS criteria, patients must have positive polysomnography results and be aware of and report symptoms such as hypersomnia. In contrast, a diagnosis of obstructive sleep apnea is based only on objective polysomnography results. If the prevalence of obstructive sleep apnea had been used, the ARP and therefore the number of affected drivers, collisions, and fatalities, would all be much higher. When determining the cost of OSAS treatment with CPAP, we assumed that each driver with a diagnosis of OSAS would undergo 2 complete polysomnograph studies—1 for diagnosis and one for CPAP titration. Most sleep centers now complete both diagnosis and CPAP titration all within 1 night's sleep study. CPAP compliance and effectiveness has been reported to be from 65% to 89%.[25] A conservative estimate of 70% was used to reduce the risk of benefit overstatement. Screening costs were generously calculated such that 1 out of 5 individuals undergoing a laboratory sleep study is diagnosed with OSAS. However, studies have shown that 70% to 75% of patients who undergo polysomnographic study actually receive a diagnosis of OSAS.[39] Also, when determining treatment costs, future expenditures were not discounted to current values as yet another means of reducing the risk of overstatement of the results.

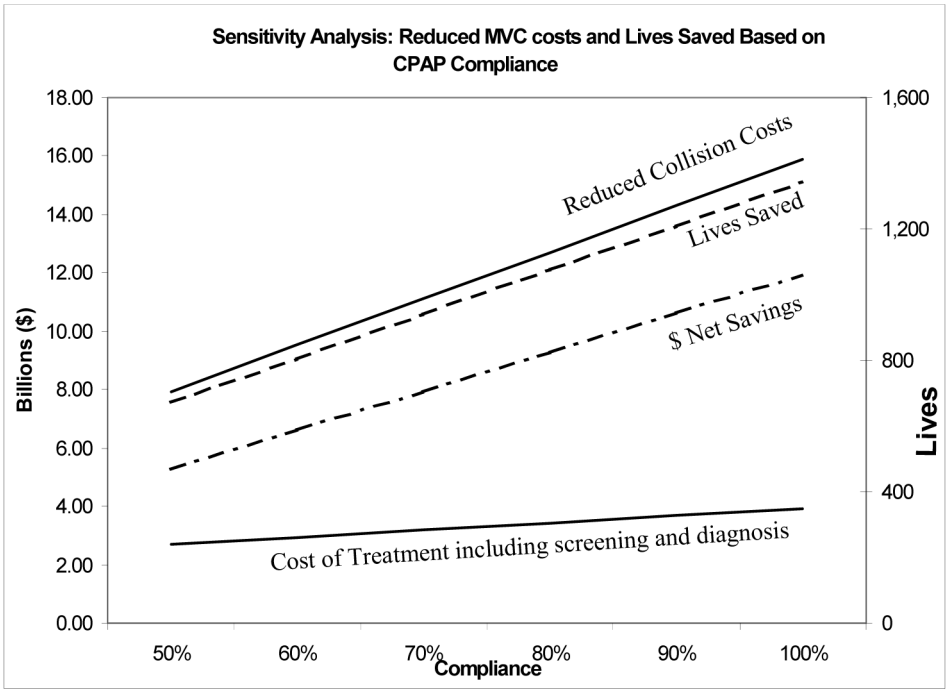

Figure 3—This sensitivity analysis shows the correlation between CPAP compliance rate and related annual savings in lives and U.S. dollars. As patient compliance increases, collision costs are reduced lives saved and net savings (reduced costs of collisions - cost of treatment) significantly increase.

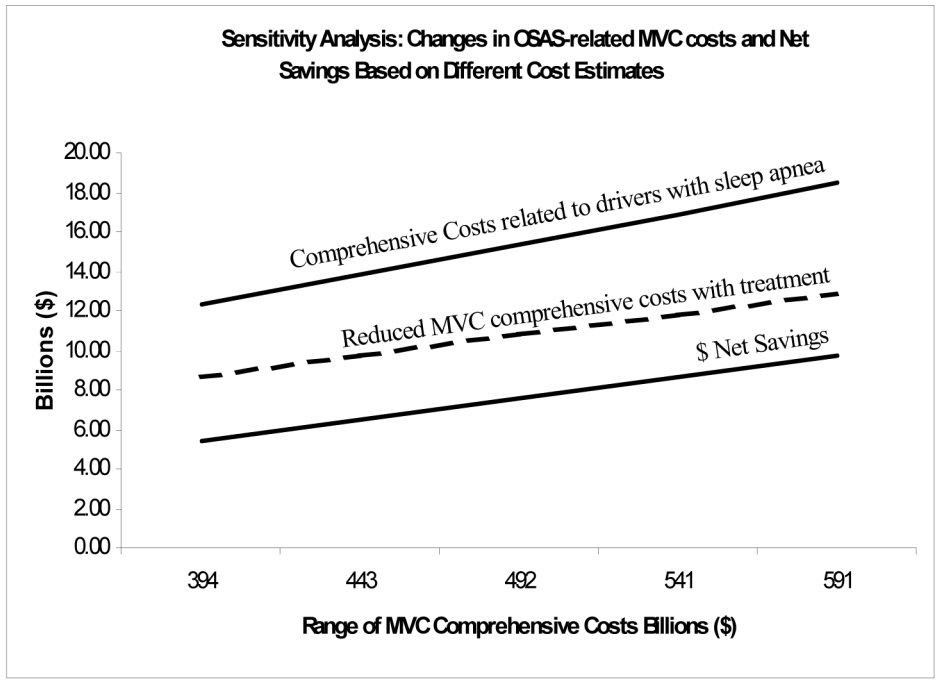

Figure 4—This graph demonstrates how the monetary results may vary if the comprehensive annual motor vehicle collision cost is different than the $492 billion utilized in this study. Monetary results of this study include annual collision costs related to obstructive sleep apnea syndrome (OSAS), reduced collision costs with treatment of drivers with OSAS, and annual net savings (reduced costs of collisions - cost of treatment).

In 1996, a panel published 3 articles in which they discussed the role of cost-effectiveness analysis in health care and made several recommendations.[40-42] While as of yet, the recommendations have not been fully adopted by the medical and scientific community, we have adhered to their recommendations applicable to our cost-benefit analysis, which is significantly different from a cost-effectiveness analysis. Moreover, this study is inclusive in its treatment costs. Yet, it only considers the benefits limited to reduced collisions, collision costs, and collision deaths. Valuation of other established benefits related to cardiovascular disease, diabetes mellitus, improved work productivity, and others are beyond the scope of this study.

Non-CPAP treatments such as weight loss (surgical and nonsurgical), maxillomandibular advancement, laser correction, uvulopalatopharyngoplasty, and oral appliances were not considered, since their efficacy in preventing collisions has not been fully established.

Limitations

Diverse sources of data inherently increase the risk for error. As more information about OSAS is gained, definitions are being modified and rapidly changed. This makes it difficult to accurately interpret data and compare studies. Publication bias in the meta-analysis is unlikely as some of the largest studies show the largest ORs. English language and database biases may be present. We deem the OR used in the ARP equation to approximate the relative risk with an immaterial, if any, difference. The pooled OR includes more than 1,290 subjects. The 95% CI is a narrow 1.84-3.45. Given the number of studies showing increased risk of collisions in drivers with OSAS, decreased motor-cognitive function, and the scientific plausibility behind such an association, a pooled OR of 2.52 is conservative and reasonable.

Ideally, the apnea-hypopnea index (AHI) of subjects used to estimate prevalence of sleep apnea should proximate the AHI of subjects used in the meta-analysis. We could not achieve this due to differences between definitions of obstructive sleep apnea 'syndrome' and obstructive sleep apnea. Obstructive sleep apnea is based on objective measures such as

AHI. However, as used in Young's paper[4], OSAS (with 'syndrome') means that the driver is subjectively aware of the effects of the obstructive sleep apnea and reports such symptoms without denial. The same paper reports that of those with obstructive sleep apnea, women report higher prevalence of hypersomnolence (OSAS) than do men, and that the actual prevalence of hypersomnolence (OSAS) may be significantly higher than reported by subjects. Moreover, others have also shown that subjective self-reported hypersomnolence may be misleading and unreliable.

The 3% prevalence rate of OSAS was used in this study because it is the most common accepted and used prevalence rate. Furthermore, while Young et al[4] report hypersomnolence in those with an AHI of 5 and greater, which was used to estimate the OSAS prevalence, the hypersomnolence rate of those with higher AHIs was not reported. If 50% of men and women with an AHI ≥ 10 in Young et al's study reported hypersomnolence, the OSAS prevalence for men and women aged 30 to 60 years, would be estimated at 7.5% and 2.5%, respectively; yielding a 5% average for OSAS prevalence rate.

Finally, most of the collision data are from clinic populations and not the general population. Clinic patients may have more-severe OSAS and may be poorer drivers with higher collision rates. Two studies not involving clinic patients have shown a high OR of having a collision compared to that of controls. Young et al[11] found that male drivers with OSAS from a population of government employees had a 3.96 OR of having a collision (95% CI, 1.69-9.14) compared to controls without OSAS. Teran-Santos,[17] in a study not involving clinic patients, found that drivers with OSAS had an OR of 6.3 (95% CI, 2.4-18.2) for having a collision.

While based on the data presented, we believe that treating drivers with OSAS will result in reduced collision deaths and increased monetary savings, we have not analyzed other non–health-related programs that may also reduce collisions, costs, and collision fatalities. Moreover, this cost-benefit analysis is from the viewpoint of society as a whole. If this analysis is viewed from a medical insurance company's perspective, the cost of treatment outweighs the benefit of reduced medical expenses related to motor-vehicle collisions. However, treating OSAS reduces medical expenses independent of collision costs as health benefits extend beyond reducing collisions. From the automobile-insurance industry's viewpoint, paying for screening, diagnosis, and treatment of OSAS would outweigh the benefit of reduced property claim payouts.

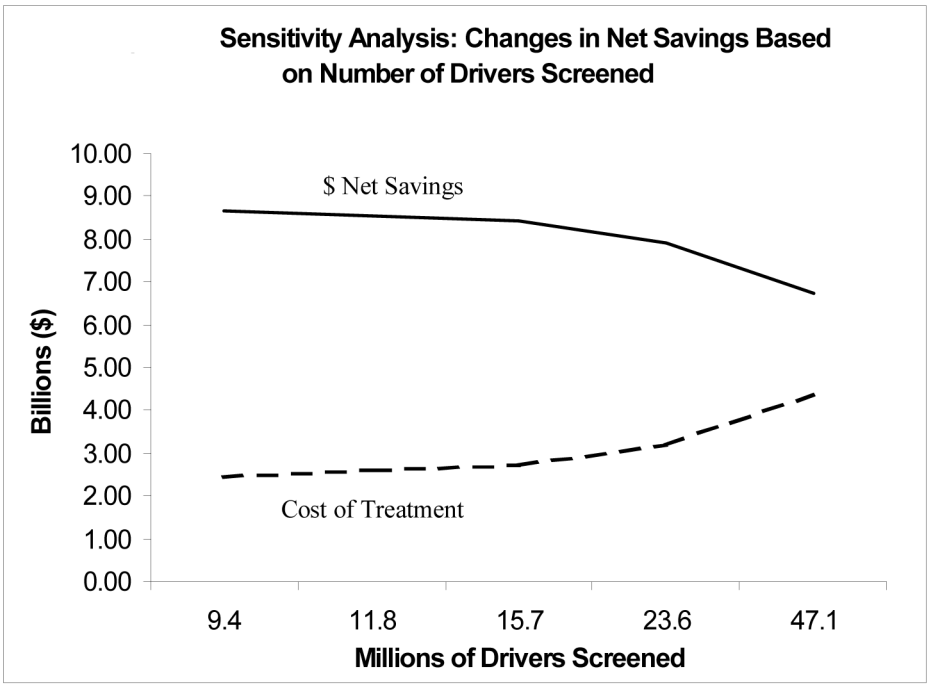

Figure 5—Illustrated is a graphic representation of the correlation of the annual cost of treating drivers with obstructive sleep apnea syndrome (OSAS) and the annual net savings (reduced costs of collisions - cost of treatment) in relation to the number of drivers screened with polysomnography for OSAS. In a screening range of approximately 10-50 million drivers, total cost of treatment increases and the annual net savings decrease as number of drivers screened increases.

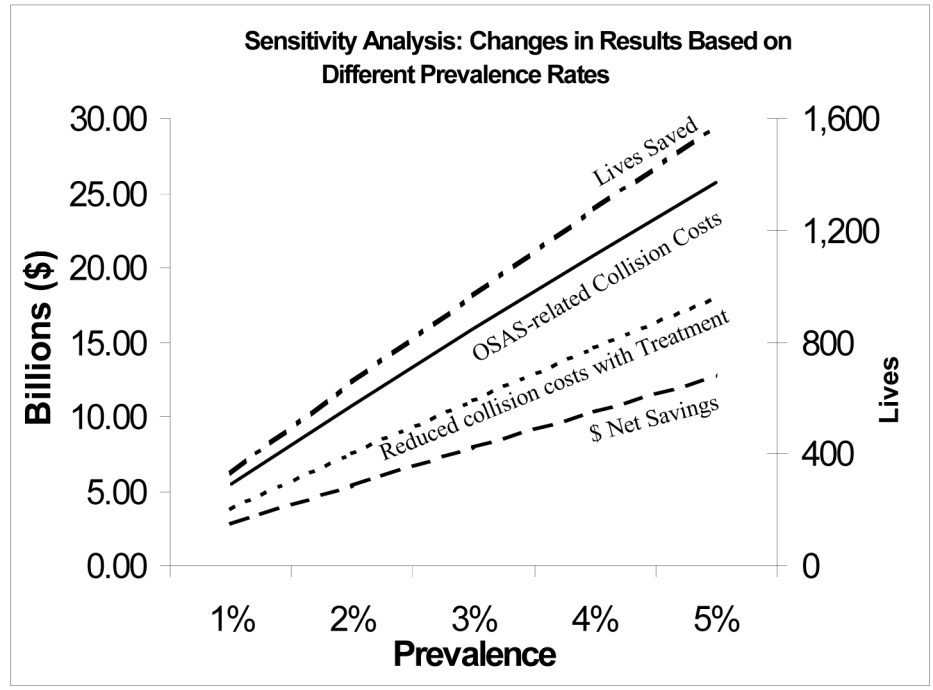

Figure 6—Sensitivity analysis graph exhibits the relationship between prevalence of obstructive sleep apnea syndrome (OSAS) and the annual motor vehicle collisions, collision costs, net savings (reduced costs of collisions - cost of treatment) and annual lives saved. The higher the prevalence of OSAS among drivers; the more motor vehicle collisions and their associated losses are prevented by treating drivers with OSAS.

CONCLUSION

OSAS contributes to many collisions annually. The consequences are great, both in terms of monetary costs and lives disrupted. Based on our analysis, the minimum estimates of annual OSAS-related collision costs, collisions, and fatalities are $15.9 billion, 810,000 collisions, and 1,400 fatalities. This is an enormous burden and demands attention. CPAP treatment can annually reduce collision costs by $11.1 billion, prevent more than 500,000 collisions, and save nearly 1,000 lives. The United States can save nearly $8 billion per year with CPAP treatment (for every $1.00 spent on CPAP treatment, $3.49 will be saved in reduced collision costs). These savings do not take into account the other economic, medical, and social benefits of treating OSAS, including decreased accidents at work,[14] decreased hospitalization costs,[34,35] and the improved quality of life.[43] Treating drivers with OSAS benefits both the patient and the public.

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