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STATE OF THE ART REVIEW

The Economic Impact of Obstructive Sleep Apnea

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Abstract Untreated obstructive sleep apnea (OSA) increases healthcare utilization and is associated with reduced work performance and occupational injuries. The economic burden related to untreated OSA is substantial, accounting for billions of dollars per year. Furthermore, therapy of OSA is an extremely cost-efficient use of healthcare resources, comparing highly favorably with other commonly funded medical therapies. Governments, transportation agencies, industry, and insurance companies need to be better informed concerning the economic impact of untreated OSA and the benefits of therapy.

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Introduction

Obstructive sleep apnea (OSA) is a common underdiagnosed respiratory disorder characterized by recurrent upper airway obstruction during sleep [1, 2]. The resultant sleep fragmentation and repetitive hypoxemia have a variety of adverse consequences, including excessive daytime sleepiness, reduced quality of life, activation of the sympathetic nervous system, endothelial dysfunction, and neurocognitive impairment. Furthermore, patients with OSA are at increased risk of cardiovascular disease and motor vehicle crashes [3, 4]. Given the high prevalence of this disease, the economic costs of OSA have substantial relevance.

In this article we review the potential economic impacts of OSA, specifically focusing on (1) the effects of OSA on work limitation, occupational injuries, and healthcare costs, (2) the economic burden of disease, and (3) the cost-effectiveness of continuous positive airway pressure (CPAP) therapy.

Work Limitation

A substantial proportion of patients with OSA participate in the workforce. Given that sleepiness negatively affects cognitive function, one would expect that patients with OSA would suffer from impaired work performance [5]. However, relatively few studies have examined the relationships between work limitation, OSA, and sleepiness. Ulfberg et al. [6] studied a random sample of the general population (n = 285,223 nonsnorers and 62 snorers) and compared them to 351 patients (289 snorers, 62 patients with OSA) referred to the sleep disorder clinic for suspected OSA. Compared to control nonsnoring subjects, patients with OSA were significantly more likely to complain of difficulty doing their job because of tiredness/sleepiness (odds ratio [OR] = 37). Furthermore, patients with OSA were significantly more likely to complain of large or very large difficulties in concentrating on new tasks (OR = 7.5), learning new tasks (OR = 9.1), and performing monotonous tasks (OR = 20).

Recently, Mulgrew et al. [7] administered a validated instrument to measure four dimensions of work limitation (Work Limitations Questionnaire, WLQ) [8] to 428 patients referred for suspected OSA. In the group as a whole, there was no significant relationship between severity of OSA and the four dimensions of work limitation; the authors attributed this lack of relationship to the nature of the population (patients referred for sleep-related complaints) and the broad differential diagnosis of fatigue. However, there were strong associations between subjective sleepiness, as assessed by the Epworth Sleepiness Scale (ESS) score and three of the four scales of work limitation. Patients with an ESS score $\leq$ 5 had much less work limitation than those with an ESS score $\geq$ 18 in terms of time management (limited 19.7% of the time vs. 38.6%, $p < 0.001$), mental-interpersonal relationships (15.5% vs. 36.0%, $p < 0.001$), and work output (16.8% vs. 36.0%, $p < 0.001$).

To our knowledge, only four publications have assessed the effect of treatment for OSA on work performance; all were before/after design and none used a control group. Ulfberg et al. [9] evaluated 152 patients with substantial OSA (index > 20/h) who answered four questions concerning self-perceived work performance before and after using CPAP for 6 months. After CPAP, patients were significantly less likely to report difficulty in performing their job due to tiredness or sleepiness (66% vs. 24%, $p < 0.001$), and patients were significantly less likely to report difficulty concentrating on new tasks, learning new tasks, and performing monotonous tasks ($p < 0.000001$). Similar results were obtained in another study of 33 OSA patients who were using CPAP; in this study there were significant improvements in time management (limited 26% of the time vs 9%, $p < 0.001$), mental-interpersonal relationships (16% vs. 11.0%, $p = 0.014$), and work output (18% vs. 10%; $p < 0.009$) dimensions of the WLQ in CPAP-treated patients [7]. CPAP also increased subjective job productivity (as measured by a 10-point scale) from 6.8 to 8.4 ($p < 0.001$) in a group of 316 patients with sleep apnea in Ohio [10]. Finally, Arai et al. [11] documented improved work performance in a small sample (n = 9) of patients treated with a dental appliance. Although the four studies were relatively small and lacked control groups, treatment of sleep apnea seems to improve work performance and is consistent with studies that have shown improvements in sleepiness in patients with OSA treated with CPAP [12].

Occupational Injuries

Occupational injuries are a major societal problem. In the United States in 2005 there were 5702 work-related fatal injuries, with 4.0 deaths per 100,000 workers per year [13]. Sleepiness due to OSA adversely affects vigilance and performance [14]. These deficits in neurocognitive performance lead to errors while driving and result in increased risks of motor vehicle crashes, including a high rate of collisions in patients who drive as part of their occupation [15]. One would similarly expect increased risks of occupational injuries in patients with OSA. Although few studies have addressed the issue of occupational injuries in patients with sleep apnea, those that have been published suggest a substantially increased risk in patients with OSA.

In a 10-year retrospective study comparing occupational accidents between 704 patients suffering from sleep-disordered breathing (diagnosed by a screening tool) and 580 age-matched random samples drawn from the general population, there was a 1.8-fold increase in occupational accidents among male snorers and 50% increase among men suffering from obstructive sleep apnea syndrome [16]. In females, the risk increased by at least threefold among heavy snorers and sixfold in sleep apnea syndrome patients. One major limitation of this study was the lack of polysomnography, which may have diluted the effect of OSA.

Similarly, in a population-based study, Lindberg et al. [17] studied 2874 men aged 30–64 years who answered questions on snoring and daytime sleepiness. Ten years later, 2009 responded to a follow-up questionnaire that included work-related questions. Three hundred forty-five occupational accidents were reported by 247 of the men (12.3%) as obtained from national registry data. Men who reported both snoring and excessive daytime sleepiness at baseline were at increased risk of occupational accidents, with an adjusted OR of 2.2 (95% CI = 1.3–3.8). Although sleep studies were not performed, these data strongly suggest that OSA increases rates of occupational accidents.

Spengler et al. [18] studied predictors of injuries in a cross-sectional survey of 1004 Kentucky farmers. In a telephone interview, 121 farmers reported an injury in the previous year; 6.7% of farmers had three symptoms of OSA (snoring, gasping and snorting, stopping breathing).

These individuals had a significantly higher rate of injuries than those with no symptoms (19.4 vs. 10%), a difference that persisted after controlling for a variety of potential confounders (OR = 2.48, 95% CI = 1.13-5.41).

Economic Burden of OSA

Although the exact costs are difficult to gauge, OSA appears to cause a huge economic burden (billions of dollars per year) and is comparable to other chronic diseases. The economic burden of OSA-related automobile collisions alone is enormous. Patients with sleep apnea have a three- to sevenfold increased risk of motor vehicle crashes, and CPAP reduces these risks substantially [19, 20]. Sassani et al. [21] estimated the annual costs associated with OSA-related motor vehicle crashes in the United States. Using year 2000 data from published studies and the National Safety Council, they estimated that 810,000 collisions and 1400 fatalities were attributable to sleep apnea, with a total cost of 15.9 billion dollars. Treatment with CPAP would prevent 567,000 of these crashes, save approximately 1000 lives, and result in an overall savings of 7.9 billion dollars after costs associated with treatment were taken into account.

In the most comprehensive study to date, Hillman et al. [22] evaluated the cost of sleep disorders (mainly OSA, insomnia, and periodic limb movements of sleep) in Australia. They evaluated the nature and magnitude of these costs, including the direct health costs of managing these sleep disorders and associated medical conditions; the indirect financial costs of associated work-related injuries, motor vehicle crashes, and lost productivity; and the nonfinancial costs derived from loss of quality of life and premature death (suffering). A literature search was used to establish the prevalence of common sleep disorders and epidemiologic evidence for the "attributable fractions" of other health impacts associated with these sleep disorders.

Direct health costs were derived from recurrent cost data for 2000-2001 extrapolated to 2004 based on demographic growth and inflation (expressed in U.S. dollars using 2004 Organization for Cooperation and Development purchasing power parity of 72.8 U.S. cents per Australian dollar). The total economic burden of sleep disorders in Australia (a country with a population of 20.1 million) was substantial: $7.494 billion in 2004 (Table 1). The financial costs, excluding the cost of suffering, were $4.524 billion, representing 0.8% of Australia's gross domestic product, and the cost of suffering totaled $2.970 billion. The cost of sleep disorders, when extrapolated to the U.S. population (i.e., more than ten times the population of Australia), would be greater than the economic burden of asthma (estimated to be 11 billion U.S. dollars in 1994) [23] and chronic obstructive lung disease (32 billion dollars in 2002) in the United States [24]; indeed, the costs would be of similar magnitude to that of diabetes (132 billion dollars in 2002) [25].

Healthcare Utilization

Untreated OSA leads to multiple medical problems (such as systemic hypertension, cardiovascular disease, injuries, and mood disorders) that potentially increase healthcare utilization. A number of studies in various countries have shown that untreated patients with sleep apnea consume a disproportionate amount of healthcare resources and that healthcare expenditures decrease after treatment [26].

Kapur et al. [27] evaluated 238 adult patients with OSA who were members of a U.S. health maintenance organization. These patients were matched to 476 control subjects with similar duration of enrollment. The authors compared the direct medical costs of patients with and without sleep apnea during the year prior to diagnosis. Mean annual medical costs for OSA patients were significantly greater ($2720) than those of the matched controls ($1384); OSA

Table 1 Summary of costs related to sleep disorders in Australia (adapted from [22])

Direct health costs:	
Costs from diagnosis/treatment of sleep disorders	$146 million
Costs from associated conditions (e.g., cardiovascular disease, diabetes, depression, work-related injuries, motor vehicle crashes)	$313 million
Indirect costs:	
Work-related injuries, including production disturbance, legal, investigation, human capital, travel, funerals	$1,956 million
Motor cehicle crashes, including long-term care, workplace/labor disruption, quality of life, legal costs, repairs, towing, travel delays, administration, police, property damage	$808 million
Other costs	$1,301 million
Net cost of suffering	$2,970 million
Total	$7,494 million

Costs are in 2004 US$

patients had higher mean costs than controls even after adjusting for chronic disease score. Furthermore, severity of sleep apnea was associated with increasing healthcare utilization. Similar results were obtained in a study from Israel by Tarasiuk et al. [28]. In the 24 months before diagnosis, patients with sleep apnea consumed 1.7 times more healthcare resources than controls matched for age, gender, area of residency, and family physician (annual cost of $948 U.S. compared to $571).

Therapy of OSA appears to reduce healthcare utilization. Albarrak et al. [29] evaluated 342 men with OSA and a group of matched controls. Patients who used CPAP or bilevel positive airway pressure for five nights or more per week in the five years following diagnosis were included in the study. For each patient, four control subjects were identified who were matched for age, sex, family physician, and postal code selected from the Manitoba provincial health database. The mean total physician fees in the year before diagnosis was $148.65 (95% CI = 95.12-202.10) greater than the total fees in the fifth year before diagnosis, suggesting a negative impact of OSA on healthcare utilization. Also, during the fifth year after diagnosis, total fees were $13.92 (95% CI = -68.68 to 40.83) less than the year before diagnosis, suggesting a beneficial effect of CPAP. In controls, the increase in fees from the fifth to the first year before diagnosis was more modest (i.e., $19.62), and there was an increase (rather than a decrease) in fees by $47.52 from the first to the fifth year after diagnosis.

Cost-Effectiveness of CPAP Therapy

Cost-effectiveness is usually assessed by the incremental cost-effectiveness ratio (ICER), which is the ratio of the incremental cost and incremental change in quality adjusted life years (QALY) that follows from the adoption of a treatment (in this case CPAP) or lack thereof. In general, an ICER of $50,000 per QALY is considered to be cost-effective, although there is some evidence that this value should be greater [30]. A number of studies in various countries have evaluated the cost-effectiveness of CPAP therapy for OSA. In general, they demonstrated that CPAP is a very cost-effective use of healthcare resources and compares highly favorably with other therapeutic interventions [31].

Mar et al. [32] performed a cost-effectiveness analysis of CPAP therapy in patients with moderate to severe OSA in Spain. The impact of CPAP on quality of life, fatalities due to motor vehicle collisions, and morbidity/mortality due to cardiovascular disease was used in their economic model. The ICER was well within the range of what would be considered cost-effective (7,861 euros per QALY saved). This model may be very conservative because costs related to motor vehicle collisions were not considered.

CPAP also appears cost-effective in an American context [33]. Using a Markov economic model that included benefits of CPAP (related to reduction in motor vehicle crash risk and improved quality of life) and costs of therapy (including device and physician costs) in patients with moderate to severe disease, the ICER of CPAP was found to be $3,354 U.S. per QALY gained from the perspective of the healthcare system. From a societal perspective (i.e., including losses from work productivity, insurance, property damage), the ICER was $314 per QALY gained. Using similar methodology, ICER in a Canadian context were $3,626 CDN and $2,979 CDN from the healthcare system and societal perspective, respectively [34].

These data are highly consistent and demonstrate that the ICER of CPAP is substantially lower than the commonly accepted threshold value of $50,000 per QALY. This is despite the fact that many of these models were very conservative and are likely a gross underestimate of the impact of CPAP. That is, they did not include the benefits in terms of improving work productivity, reducing rates of occupational injuries, and improving spousal quality of life [35]. CPAP compares very favorably with a variety of commonly funded medical treatments such as the use of cholesterol-lowering medications in the primary prevention of cardiovascular events ($54,000-1,400,000/QALY gained) [36], biologic agents for the treatment of rheumatoid arthritis ($30,500/QALY) [37], and lung volume reduction surgery in the treatment of severe emphysema ($190,000/QALY) [38] (see Table 2 for ICER of various diseases).

Conclusions

OSA is an important public health problem. It is common and is associated with reduced quality of life, decreased cardiovascular health, and increased healthcare utilization, transportation accidents, and mortality. There are several well-tolerated and effective treatments that have been shown to improve quality of life and cardiovascular health and reduce healthcare utilization and motor vehicle crashes [39, 40]. Despite this, the majority of people with OSA remain undiagnosed and untreated. Furthermore, there is considerable variability in diagnosis of and treatment for OSA across countries, and even different regions in a country (e.g., across provinces in Canada) [41]. In Canada, for instance, many patients wait months to be diagnosed and the majority of the provincial medical plans do not provide financial coverage for CPAP treatment [42]. Similar to other common chronic disorders such as asthma and diabetes, there needs to be a patient awareness program regarding the symptoms and consequences of OSA that includes information about maximum wait times for diagnosis and treatment. This should be complemented by the

Table 2 Incremental cost-effectiveness ratios (ICER) of various medical interventions

Ref.	Interventions compared	Design	ICERs	Conclusion
[44]	Vaccination against HPV subtypes 16 and 18 with either (1) delayed screening; (2) no screening; (3) no vaccination	Markov model	$44,889/QALY US for the vaccination + delayed screening vs. screening only	HPV vaccination plus screening is cost effective
[45]	Fluticasone propionate vs. placebo for the treatment of COPD	Economic analysis conducted alongside a clinical trial	9,500 £ ($19,380 US)/QALY for fluticasone vs. placebo	Fluticasone for asthma appears cost effective
[46]	Primary angioplasty vs. medical management for reperfusion after a myocardial infarction	Economic analysis conducted alongside a clinical trial	9,241 £ ($18,852 US)/QALY for primary angioplasty vs. medical management	Primary angioplasty is cost effective for the treatment of acute myocardial infarction
[47]	Prophylactic implantation of an ICD, as compared with control therapy	A meta-analysis of clinical trials to inform a Markov model	Depending on the population, cost-effectiveness of the ICD as compared with control therapy ranged from $34,000 to $70,200/QALY	In populations in which a significant device-related reduction in mortality has been shown, prophylactic implantation of an ICD has a cost-effectiveness ratio below $100,000/QALY
[48]	Mechanical ventilation for at least 21 days to a 65-year-old critically ill patient compared with the provision of comfort care resulting in ventilation withdrawal	Markov model	Providing prolonged mechanical ventilation vs. ventilation withdrawal $82,411/QALY	Cost effectiveness of prolonged mechanical ventilation provision varies dramatically based on age and likelihood of poor short- and long-term outcomes
[49]	Lung volume reduction surgery vs. medical treatment in patients with emphysema	Economic analysis conducted alongside a clinical trial	$190,000/QALY saved for surgery vs. medical treatment	Lung volume reduction surgery is costly relative to medical therapy; surgery on some subgroups may be more cost effective

CPAP for the treatment of sleep apnea compares highly favorably, with ICER generally less than $4,000/QALY (see text)

development of a comprehensive strategy that provides timely diagnosis and treatment of OSA [43]. Governments, transportation agencies, industry, and insurance companies need to be better informed about the economic impact of untreated OSA and the benefits of therapy.

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