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Sebastian Riethmüller, Ruedi Müller-Wenk[1], Andreas Knoblauch, Otto D. Schoch

Department for Pneumology and Multidisciplinary Sleep Center, Kantonsspital, St.Gallen, [1]Institute for Economy and the Environment, St.Gallen University, Switzerland

ABSTRACT

Study Objectives: To design a national antinoise policy, we need to know the monetary value that people attach to the reduction of sleep disturbance due to road traffic noise. Principles: Patients with obstructive sleep apnea syndrome (OSAS) controlled by nasal continuous positive airway pressure (nCPAP) underwent one-to-one structured interviews to determine the monetary value of their resultant undisturbed sleep. This was then converted into a value for sleep undisturbed by noise, using a severity ratio. Setting: Outpatient interviews in 67 OSAS patients (54 males, 28 to 73 years old) managed by the Center for Sleep Medicine, Kantonsspital, St. Gallen, Switzerland. Mateials and Methods: The interview questions addressed the outcome and difficulties of nCPAP therapy, the self-rated severity of pretreatment sleep disturbance and self-rated monetary value of sleep improvement. Thirteen OSAS patients who had also experienced noise-related sleep disturbance rated its severity on a visual analogue scale (VAS). Results: The mean monetary value of nCPAP-controlled sleep disturbance was Swiss francs (CHF) 70/night (CHF1 = US$ 0.877, year end 2004; 25th and 75th percentiles: CHF 35 and CHF 100). Interviewees maintained this high estimate after learning that the actual treatment costs were only approximately 6 CHF/night. A severity ratio ranging from 2.3:1 to 4.7:1 for sleep disturbance resulting from OSAS or from noise was derived from patients' responses and literature. The value of noise-free sleep was CHF 7.45-23.81 per night. Conclusion: Sleep undisturbed by noise has a remarkably high monetary value for people, which should be considered in political decision-making.

Keywords: Continuous positive airway pressure, monetary equivalent, noise, obstructive sleep apnea syndrome, road traffic, sleep disturbance, willingness to pay

Introduction

Noise is a source of human health impairment, particularly, traffic noise at night is an important source of sleep disturbance.[1] The amount of health damage, an important factor for noise policy development, can be represented by the number of affected cases and their severity. Two distinct methods are used to express the the severity of a given health impairment: Either a severity indicator (disability weight, DW) is determined, describing the degree of the health damage relative to a reference state of health or the severity is represented by an equivalent in money units.

The concept of DW has been developed by Murray *et al.*[2] for the World Health Organisation (WHO) and the corresponding concept of disability-adjusted life years (DALY) is now used by WHO to calculate a country's burden of disease originating from the various types of health impairment. The DW of a human year of life lived in full health is fixed to 0, a year of life lost by premature death is fixed to 1 and DWs between 0 and 1 for a large number of diseases have also been developed by expert panels.[2] The DWs are fixed on the basis of actually perceptible physical, psychological and social limitations due

to a particular disease excluding risks for secondary diseases. Using this concept, Müller-Wenk has found a DW of 0.055 for living a year with regularly occurring sleep disturbance from nocturnal road traffic noise.[3]

On the other hand, the monetary equivalent of various types of health impairment, particularly, health impairment due to noise, has been the object of many previous studies. Müller-Wenk and Hofstetter[4] have discussed a choice of such studies and they attempted to quantify noise-related damage in monetary terms, deriving the cost of noise-related sleep disturbance (NRSD) from recent studies on the noise dependency of apartment rents as well as from studies on people's willingness to pay (WTP) to avoid specified diseases. The result was a monetary value of CHF 7 to 41 per person and night for sleep disturbance (persons declaring themselves as "highly annoyed") due to road traffic noise. Unfortunately, this monetary value is of limited use for political decision-making because of its wide range and because of methodical problems in monetization.

When analyzing prices actually paid for apartment rents and houses, it appears possible to isolate the location's noise level

as a factor for price building. However, the difficulty is to attribute the price for noise to the various health consequences and nonhealth consequences of this noise. On the other hand, WTP studies, which fix a price for avoiding a certain health impairment on the basis of interviewing a sample of persons, face the problems of ensuring comprehension by the participants of the specific health situation to be valued and of making extremely small probabilities of disease occurrence to be valued understandable to participants.

The aim of the present study was therefore to improve the quality of monetary valuation of sleep disturbance by asking successfully treated OSAS patients how much money they would see as an adequate equivalent of regaining healthy sleep thanks to nCPAP therapy. Our approach offers several advantages over conventional WTP studies (for critical analysis of the WTP approach in the context of health valuation, also see Reference 4):

1. The health damage in question and its treatment are entirely familiar to the OSAS patients. This is in contrast to typical WTP studies, where participants are requested to value the relief from an unfamiliar disease by some fictitious therapy, leading to an increased risk of misinterpretation.

2. The health damage avoided and the therapy to be valued are for the same period, *e.g.*, last month's relief from nonrestorative sleep effected by the use of the rented nCPAP equipment during the same month. In contrast, participants of typical WTP studies are confronted with the complex problem of estimation of a monetary value for a therapy applied now with a beneficial effect on future health, possibly for the whole lifetime. This leads to uncontrollable discounting effects.

3. A successful nCPAP therapy reduces the risk of sleep impairment by breathing problems from 1 to almost 0,[5,6] so that the OSAS patient can value clear health states without taking into account probabilities. In contrast, participants in typical WTP studies are requested to say how much money they would pay for a therapy that reduces the annual probability to be hit by a given disease, *e.g.*, from 500/100,000 to 200/100,000. Such small probabilities are hardly intelligible to the participants, which may lead to heavily distorted results of WTP.

4. The relationship of OSAS patients to their hospital is close. Thus, it may be expected that they are prepared to cooperate seriously in an oral interview with the hospital's representative. In contrast, participants in typical WTP studies have no relationship with the organizers of the study and may be tempted to save their time by giving quick or frivolous answers.

5. Typical WTP studies ask participants to fix a therapy's monetary value under the restriction of their own budget situation. If a participant lives at subsistence level, his correct answer would be that he would pay nothing for the therapy, in spite of its value for his future health. Attributing monetary values under personal budget restriction is adequate if WTP is used for market research

of future consumer products like a new chewing gum. But in our study, we want to know how people rate the value of a night with undisturbed sleep compared to other objects of daily consumption, like a cinema ticket or a meal; poor people should not be excluded from expressing their true judgement. We therefore, asked OSAS patients to freely express their monetary equivalent (ME) of successful nCPAP therapy. Only in a subsequent step did we ask them how the amount mentioned would change (now called willingness to pay, WTP) if they had to consider their actual budget restrictions.

However, the main purpose of the study was to monetize the recovery of undisturbed sleep achieved by eliminating nocturnal road traffic noise and not the value of eliminating breathing problems. This required a benefit transfer from the monetary value of eliminating OSAS to that of eliminating NRSD, based on establishing a severity ratio between the symptoms of OSAS *vs* NRSD. Our study used three methods to establish this ratio: Literature data, local clinical expert opinion and the experience of OSAS patients who had suffered both forms of sleep disturbance in their past.

Materials and Methods

Patients

There were some 15,000 Swiss patients with OSAS in 2003 treated by nCPAP, according to the Swiss Lung Association (www.lungenliga.ch) including 13,500 patients from its own database and an estimated 1,500 treated under other auspices. This represents just under 0.21% of the Swiss population. There are no strong reasons for assuming substantial differences in valuations of nCPAP therapy between patients in the St. Gallen canton and the rest of Switzerland: annual per capita incomes are CHF 40,983 in the St. Gallen canton and CHF 48,840 in Switzerland as a whole. Individuals older - than 50 years of age account for 31.0 and 33.1% of the population, respectively (2000 data).[7] These similarities enabled us to confine data collection to the St. Gallen canton, in which all qualifying patients receive their nCPAP device from the Lung Association, a nonprofit organization now heavily involved in medical welfare services, including the care of OSAS patients. It services the nCPAP devices and supervises therapy in cooperation with physicians.[8]

The study patients were recruited from the 513 OSAS patients being treated with nCPAP in the St. Gallen canton and the Principality of Liechtenstein on November 30, 2003. All patients scheduled for the yearly nCPAP control at the sleep center during the study period and those living in the proximity of the sleep center were screened.

Incuded were OSAS patients treated by nCPAP providing "marked improvement in self-rated sleep quality" (defined by "sleep self-rated as better" and/or "more rested in the morning"

and/or "less tired during the day"). Exclusion criteria were: No "marked improvement in self-rated sleep quality", under 18 years-old, difficulty to communicate in German, nCPAP use of <two months, irregular nCPAP use (defined as less than five days per week and less than five hours per night[9]) and/or nCPAP use mainly as antisnoring therapy (for the partner's benefit). The exclusion criteria were set based on the belief that these patients were unable to give accurate estimates of a monetary value for sleep improvement.

Procedure

To improve data quality, we personally conducted oral face-to-face interviews, after providing the patients with a written introduction. We thus drew on the mutual trust between the staff of the Center for Sleep Medicine and the patient. Thus, the risk of a superficial interview was minimized while maximizing participation, cooperativeness and the sincerity of the responses. The interviewer could thus, always intervene appropriately if the patient was querulous, answering without sufficient thought or had not properly understood the question. Interviewers were not attending physicians for the patients. As the methods of benefit transfer from OSAS to NRSD were established in retrospect, the interviewers could not direct the patients to a specific monetary value.

This method was more time-consuming than a self-completed written questionnaire. Thus, the study was conducted in a sample of 513 patients drawn from two sources: 1) all nCPAP patients attending the center from March through May 2004 for annual check-up ($n = 28$); and 2) all nCPAP patients in St. Gallen City (population on January 1, 2004: 70,894) meeting the inclusion criteria on the November 30, 2003 reference date ($n = 59$). Eleven of these were disqualified by the noninclusion criteria (lack of treatment benefit: $n = 7$; language difficulty: $n = 4$), while of the remaining 48, five could not be contacted and four refused to participate, leaving 39 patients (81%) available for full interviews.

Structured interview questionnaire

An interview questionnaire was developed to identify the ME and WTP values as well as possible explanatory variables for undisturbed sleep in a sequence of steps. First, patients were asked to recall the self-perceived difference in sleep quality (including the effects of disturbed sleep on the following day) with and without the CPAP device. They were to focus solely on the improvement in sleep quality itself (*i.e.*, on the intrinsic value of undisturbed sleep) and ignore extrinsic considerations such as earnings lost due to a drowsiness-induced decrease in work performance. They were instructed to estimate the sum of money in CHF/night, which their improved sleep quality was worth to them, even if they were unable to meet the whole expense themselves in their current financial situation (thus explicitly excluding the budget limitation of WTP studies). Nevertheless, the resulting sum, termed the ME, had to be realistically related to the current prices of routine

daily expenses. This was addressed in the next question by asking the patient to check the ME against a price list for everyday goods and services, *e.g.*, newspaper, cinema ticket or rent. Lastly, budget restriction was introduced by asking the patients if they would be prepared to pay their stated ME even from their own pockets. If they answered in the negative, they were asked what was the most they could afford for the nCPAP device per night from their household budget. The result was defined as the WTP value, given its similarity to the monetary values from standard WTP studies.

Potential explanatory variables were addressed in the first part of the interview or taken from medical records:

Age and sex: Although we did not anticipate a substantial influence of age or sex on ME, it was conceivable that the elderly might attach less value to therapy because they think that certain limitations become normal with increasing age.

Pretreatment apnea/hypopnea index (AHI): The AHI usually reverts to normal during nCPAP therapy.[10] Although we anticipated only a slight effect, it was possible that the higher the pretreatment AHI, the greater would be the subjective benefit and hence, the ME, for reasons given later.

Pre- and posttreatment Epworth Sleepiness Score (ESS): The ESS is the most frequently used instrument for self-rated daytime sleepiness.[11,12] It was possible that the higher the pretreatment ESS or the greater the decrease in ESS during nCPAP, the higher the ME would be. We anticipated slight or no effect, because the ability for self-reflection, a precondition for ESS ratings, tends to change under CPAP therapy, thus distorting the ESS value. A consistently poor correlation has been found between AHI and ESS.[13]

Pretreatment OSAS self-rated on a visual analogue scale (OSAS VAS): Patients were asked to rate their pretreatment OSAS on a 10 cm VAS (0: normal sleep, 10: symptoms so unbearable that life was not worth living). We anticipated that those with relatively good sleep quality before nCPAP (*i.e.*, low OSAS VAS values) would give a lower ME.

NRSD VAS: For simplification, we defined NRSD in a dichotomous manner, according to the perception of the patients. Those patients who had experienced chronic NRSD were asked to rate its severity on a VAS identical to that for OSAS VAS.

Device use problems and side effects: Patients who found nCPAP very unpleasant to use (*e.g.*, mask problems, difficulty in exhaling) or who experienced side effects (*e.g.*, dry mucosa, flatulence) could have attached a lower monetary value to the device.

Employment status: Although the ME estimate was independent of a potential loss of earnings, it was conceivable

that unemployed patients might give a lower value. This may be because they had more time to rest during the day and would not consider such rest periods to restrict their quality of life.

Income: Patients were asked to which quartile of the Swiss household income distribution they regarded themselves as belonging to and what was their monthly rental (or rental value of their accommodation). The higher the rental figure and income class, the higher we anticipated the WTP to be, while expecting no effect on ME.

Awareness of actual treatment costs: Patients were asked if they were aware of the actual cost of nCPAP therapy and what they estimated this to be. As the cost is largely borne by health insurance funds, it is of little concern to many patients. We anticipated that awareness of the actual treatment cost would lower WTP and perhaps also ME as the relatively low cost of the nCPAP devices could influence the valuations.

We conducted eight pretest interviews, which were not incorporated in the final results. They helped us to optimize the order of questions and reformulate certain questions more clearly. Each complete interview took approximately 30 minutes.

Benefit transfer from obstructive sleep apnea syndrome to noise-related sleep disturbance

The interviews were designed to identify and analyze the ME for avoidance of OSAS, whereas our actual concern was the ME for avoidance of NRSD. Benefit transfer from one form of sleep disturbance to the other was accomplished with the determination of a severity ratio, allowing conversion of the ME of OSAS to an ME for NRSD. Linear benefit transfer is both justifiable and feasible. Despite their different causes, the symptoms of the sleep disturbances are similar (albeit with widely different weightings). Both OSAS and NRSD are dyssomnias according to the International Classification of Sleep Disorders (ICSD), 2001 revision.[14] The diseases are certainly different from a pathogenetic point of view. However, the basic mechanisms leading to excessive daytime sleepiness and/or abnormal sleep-wake patterns are characterized by an increase in the amount of autonomic-subcortical and cortical arousals from sleep for both diseases.[15-17] Benefit transfer depends on establishing a severity ratio between OSAS and NRSD, which can then be used to convert the known ME for OSAS to the projected ME for NRSD. We used three methods to substantiate the benefit transfer. Two of them employed disability weights (DW), a summary measure introduced by WHO,[1] enabling disability to be compared between diseases without recourse to physiological parameters.

We obtained our DWs from the OSAS and NRSD literature[10,17-22] and also from six OSAS specialists at St. Gallen Cantonal Hospital, none of whom were previously familiar with the OSAS DW literature. Following a written and oral introduction to the DW concept and a question-and-answer

session, the specialists were given a list of diseases complete with their DWs augmented by some diseases having DWs between 0.01 and 0.40. This was to maximize the potential for comparison within the range of the anticipated 'true' DW for OSAS based on literature. The specialists then individually assigned a DW to OSAS by comparing its average symptom severity with that of the other listed diseases.

The third method of comparing severity between OSAS and NRSD was to compare the respective VAS scores in 13 patients with personal experience of both forms of sleep disturbance. Two patients reported current and 11 previous experience with NRSD.

Statistics

For statistical analysis, the information was computerized and analyzed with a commercially available software package (SPSS for Windows, version 10; SPSS Inc, Chicago, IL 60606). Distribution normality was tested using the Kolmogorov-Smirnov test. Means were mainly compared using the Mann-Whitney U test. Correlations were calculated using Spearman's rank correlation coefficient, except for ME and WTP, for which Pearson's coefficient was used as both variables were normally distributed and interval-scaled. All significance levels were 2-tailed with significance alpha at $P < 0.05$. The ME regression equation was calculated using one-way univariate ANOVA. Multifactorial ANOVA controlling for age, gender, employment status, device use problems, awareness of actual CPAP cost, pretreatment ESS and AHI was used to determine whether including other explanatory variables could reduce the residual variance of ME.

Results

As Populations 1 and 2 did not differ in demographic characteristics or key results elicited in the interview (individual population results not shown), they were treated in subsequent analyses as a pooled sample of 513 nCPAP users in the St. Gallen canton and in Liechtenstein [Table 1].

Monetary equivalent and willingness to pay estimates for obstructive sleep apnea syndrome

Median monetary equivalent ME was CHF 70/day; 10% of responses were below CHF 20 and 10% above CHF 176. ME correlated moderately with OSAS VAS ($r = 0.55$, $P < 0.001$), but not with income. Given the good correlation between income quartile and rent - $r = 0.70$, $P < 0.001$ - we used rent as the income variable in our analyses as it was interval-scaled unlike income class. The regression equation:

$$ME = 26.8 \times OSAS\ VAS - 74.0$$

relates ME to OSAS VAS and accounts for 25% of the variance of ME. The residuals, *i.e.*, the deviations of individual ME values from the regression line, were nonnormally

n = 67, 54 male, 13 female	Mean	SEM	Median	Percentile	
				25	75
Age [years]	54.1	1.2			
Apnea-hypopnea index [events/h]			35	19	53
ESS before treatment [points]			12	8.8	16
ESS on treatment [points]			7	5	10
OSAS severity VAS [points]	6.2	0.2			
OSAS/NRSD VAS - ratio	2.3	0.23			
Rent [CHF/month]	1478	73			
ME monetary equivalent [CHF/night]			70	35	100
WTP willingness to pay [CHF/night]			20	13	34

CHF: swiss francs (year 2004); ESS: epworth sleepiness scale; NRSD: noise-related sleep disturbance; OSAS: obstructive sleep apnea syndrome; SEM: standard error of the mean; VAS: visual analogue scale (high = severe)
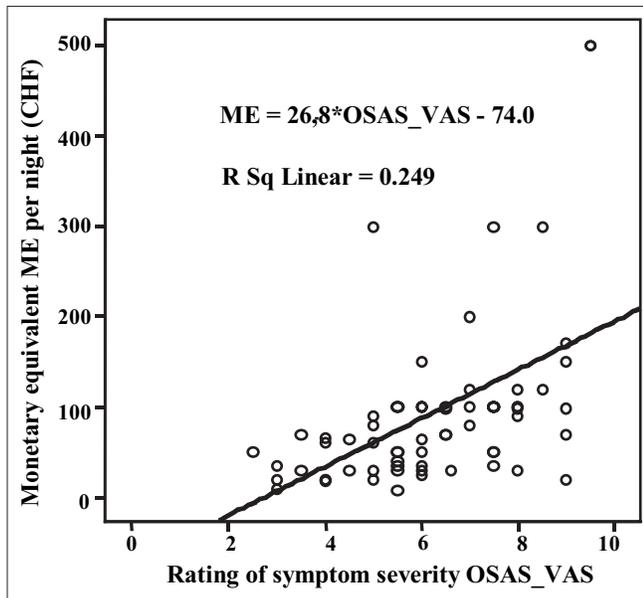

Figure 1: Regression line relating the monetary equivalent of avoiding obstructive sleep apnea syndrome (OSAS) to the visual analogue scale (VAS) rating of pretreatment OSAS symptom severity (0 = zero; 10 = maximal)

distributed. However, if the five ME estimates ≥ CHF 300 were classified as outliers and the regression line recalculated, the distribution of the remaining residuals became normal and the explained variance 27%. The regression equation confirmed our assumption that the poorer the pretreatment sleep quality rating, the higher the value assigned to successful nCPAP therapy [Figure 1].

Median WTP was CHF 20/day; 10% of responses were below CHF 10 and 10% above CHF 50. Unlike ME, WTP showed no correlation with OSAS VAS, instead, a slight correlation with income (r = 0.30, P = 0.015). ME and WTP showed only a trend towards weak correlation with each other (r = 0.22, P = 0.08).

Neither age nor sex had a statistically significant impact on ME or WTP. Employment status, device use problems and awareness of actual nCPAP treatment cost (approximately CHF 6/night, *i.e.*, much lower than patients' ME estimates) also had no significant impact. However, greater device use problems and awareness of the relatively low device cost did tend to lower ME somewhat. Statistical analysis showed that as an alternative to the above regression equation, the following line through the origin of the coordinates system:

$$ME = 22.8 \times OSAS\ VAS - 34.0 \times DP$$

would also be valid where DP is the ordinal variable for self-rated device problems with values of 1 (none), 2 (moderate) or 3 (severe).

Pretreatment ESS correlated weakly with OSAS VAS (r = 0.25, P = 0.05) but not with ME. AHI correlated with neither pretreatment ESS nor OSAS VAS.

Obstructive sleep apnea syndrome/noise-related sleep disturbance severity ratio: disability weights

Results were obtained from three sources:
Three studies had published DWs for OSAS. In a cross-sectional study, Tousignant *et al.*[10] estimated the DW for untreated OSAS retrospectively and for treated OSAS using nCPAP using the standard gamble method[20] in 19 patients. The difference between the two values, 0.24, can be viewed as approximating to the DW of OSAS. Chakravorty *et al.*[21] reported a DW of 0.23 for OSAS in a similar population, using the same standard gamble method. Mar *et al.*[22] reported a DW of 0.073 after confining their study to moderate-to-severe OSAS, excluding patients with AHI < 30 and/or no symptoms and using the EuroQoL-5D questionnaire,[23] not the standard gamble method.

Our six local OSAS specialists produced DWs for OSAS of 0.12, 0.19, 0.25, 0.27, 0.35 and 0.36 (mean: 0.26).

A DW of 0.055 for average-severity nocturnal NRSD, based on a questionnaire among 41 physicians employed by the Swiss Accident Insurance Institution (*Suva*: www.suva.ch), was taken from an earlier study.[3]

These three sources were used to construct a DW ratio between average-severity OSAS and average-severity NRSD. If we ignore the DW value of 0.073 reached using a different method by Mar *et al.*[22] - the justification for doing so is presented in the Discussion- we find a severity ratio of 4.2:1 to 4.7:1. In other words, the symptoms of average-severity OSAS are between 4.2 and 4.7 times more severe (in terms of their impact on health-related quality of life) than those of average-severity NRSD [Table 2].

Table 2: Monetary equivalent estimates for the avoidance of noise-related sleep disorder (NRSD) for different OSAS/NRSD severity ratio estimates

OSAS	NRSD	OSAS / NRSD ratio	ME percentiles for NRSD [CHF]		
			25%	50%	75%
DW 0.26 *	DW 0.055 [2]	4.7: 1	7.45	14.89	21.28
DW 0.23 [9, 21]	DW 0.055 [2]	4.2: 1	8.33	16.67	23.81
VAS 6.2	VAS 2.7	2.3: 1	15.22	30.43	43.48
DW 0.072** [22]	DW 0.055 [2]	1.3: 1	**	**	**

ME: monetary equivalent; NRSD: noise-related sleep disturbance; CHF: swiss francs (year 2004); OSAS: obstructive sleep apnea syndrome; DW: disability weight; VAS: visual analogue scale.

*Estimates of local OSAS specialists; ** Excluded because of ceiling effects of the EuroQoL questionnaire [35] (see text for details)

Obstructive sleep apnea syndrome/noise-related sleep disturbance severity ratio: Visual analogue scales

Division of the OSAS VAS ratings by the NRSD VAS ratings provided by the 13 patients with experience of both sleep disturbances yielded a mean severity ratio of 2.3:1 [Table 2]. Eleven of the 13 patients rated OSAS as being more severe than NRSD; of the remaining two, one rated them as equally severe and the other rated NRSD as more severe.

Monetary equivalent for average-severity nocturnal noise-related sleep disturbance

Division of the ME values for avoiding OSAS [Table 1] by the OSAS/NRSD severity ratios yielded an array of ME values for avoiding average-severity NRSD [Table 2]. Thus, division of the 25th percentile of the OSAS ME [Table 1] by the highest severity ratio yielded the lowest ME for avoiding NRSD (CHF 7.45 per night), while division of the 50th percentile (median) of the OSAS ME by the intermediate severity ratio, 4.2:1, yielded the presumably more representative sum of CHF 16.67 per night.

Discussion

Monetary equivalent and willingness to pay estimates for obstructive sleep apnea syndrome

Successful nCPAP therapy for OSAS largely normalizes sleep architecture[5,6] and restores undisturbed sleep. Our cross-sectional study shows that Swiss patients attach a median ME of CHF 70/night to the avoidance of symptomatic OSAS. This estimate was independent of financial status; if, for example, recovery of a night's undisturbed sleep was worth ten times the cost of a particular everyday expense, then patients had the right to state this ME, irrespective of their income limitations. The regression equation [Figure 1] confirmed the positive relationship between ME and the retrospective rating of pretreatment symptom severity - the more severe the symptoms, the higher the ME. However, this still accounted for only 25% of the variance. This proportion was only marginally increased by multifactorial ANOVA and the exclusion of very high MEs (CHF ≥ 300),

but this normalized the distribution of the residuals around the regression line, suggesting that the unexplained variance represented the normal scattering of patients' individual estimates.

When questioned on how much they would be prepared to pay out of their own pockets for the therapy they had declared to be worth CHF 70/night, patients produced a median WTP figure of only CHF 20/night. Yet this was equivalent to almost half their mean appartment rent (42%) and thus, represented a substantial sum. In contrast to ME, there was no correlation between WTP and pretreatment sleep quality. Although there was a correlation with income, as might be expected, it was weak. These results suggest that the limiting factor with WTP is the patient's financial means rather than symptom severity. The ME was 3.5 fold higher than the WTP and nonincome dependent. This was consistent with our prestudy expectation and showed we had succeeded in allowing low-income patients full scope in estimating the value of undisturbed sleep.

A simplified summary is that the median value of recovering undisturbed sleep for a Swiss patient with average-severity OSAS is CHF 70/night. Theoretically, a sum representing nCPAP device use problems should be added to this. But as we found no evidence of significant impact by such problems on ME estimates, we concluded provisionally that we could dispense with this correction. The relationship between ME and device use problems merits further study. In any event, the sum in question is likely to be small compared to the positive ME of CHF 70.

Benefit transfer from obstructive sleep apnea syndrome to noise-related sleep disturbance

Ideally, to optimize benefit transfer from OSAS to NRSD, both forms of sleep disturbance would need to be described using the same objective parameters of sleep quality and clinical severity scores generated from the resulting data. These scores would also have to correlate with the self-rated disability caused by decreased sleep quality, as it is this that states patients' monetary valuation of therapy. Such a score system would enable us to state that the symptoms of one type of sleep disturbance are approximately x times more severe than those of another.

Unfortunately, according to the current state of the art, such a score system does not exist. Two parameters often used to describe severity in OSAS are the (objective) AHI and the (subjective) ESS. In our study, the AHI correlated neither with the pretreatment ESS nor with the OSAS VAS. This is consistent to varying degrees with literature. The correlation between AHI and ESS ($r = 0.41$) found by Bennett *et al.*[24] is one of the highest published. The study validating the Spanish version of the ESS found a substantially weaker correlation ($r = 0.23$),[25] while other studies, like our own, found no correlation whatsoever.[26]

One main reason for this is probably the arbitrary nature of the definitions of apnea ("complete cessation of breathing lasting ten seconds or more") and hypopnea ("temporary decrease in respiratory flow of at least 50% lasting at least ten seconds and a decrease in oxygen saturation of 4%").[14] Upper airway narrowing at sleep onset is a continuum, from being asymptomatic in healthy subjects, through habitual and pathologic snoring, including upper airway resistance syndrome, to OSAS. Apnea and hypopnea can each last from ten to more than 60 seconds. They can trigger arousal with or without body movements, waking or merely autonomic arousal (pulse and blood pressure changes) without visible electroencephalography (EEG) arousal.[27] EEG arousals also occur in normal sleep and range in number from a few to several dozen per night. Furthermore, the interscorer variation in the scoring of arousals can be substantial.[28] In addition, AHI and the arousal index are measured only over the course of a single night, whereas night-to-night intraindividual differences occur. For these reasons, we conclude that we do not currently possess any objective parameters that adequately reflect the subjective symptoms of OSAS. With regard to our study, this means that it was impossible to compare severity between OSAS and NRSD using objective parameters. It also explains our failure to observe any correlation between pretreatment AHI and ME values.

A further complication is that NRSD is also difficult to describe using objective parameters. The sleep impact of noise depends on a variety of parameters: the noise metric and response metric chosen, the loudness and frequency of the noise, the background noise level, the meaning of the noise, sleep stage and time of night.[29,30] Sleeper characteristics also play a role, *e.g.*, individual noise susceptibility, adaptation to noise, sex, age and attitude to the source of the noise.[31-33] Last but not least, there are significant differences between field and laboratory studies.[34]

A major resource in our study for comparing symptom severity between OSAS and NRSD were DWs. Unfortunately, neither the WHO, which introduced the DW system, nor the Rotterdam group, which has since extended it to many 'diseases of affluence', have so far developed DWs for OSAS and NRSD. We therefore, had to look elsewhere. In the case of OSAS, there were three published values. Tousignant *et al.*[10] and Chakravorty *et al.*[21] both used the standard gamble approach,[20] while Mar *et al.*[22] used the EuroQoL-5D questionnaire.[23] This questionnaire was considered unsuitable for evaluating improvement in health-related quality of life in OSAS as a result of nCPAP therapy due to ceiling effects.[35] The use of this questionnaire in the population of OSAS patients has therefore been discouraged.[35] We did not include the result of this study in our analysis. The standard gamble method,[20] on the other hand, is an established procedure endorsed by the WHO for determining the DW of diseases. This left us with strikingly similar DWs from the first two studies, 0.24 and 0.23, for average-severity OSAS treatable

with nCPAP. The mean age in both studies (57 and 49 years) was similar to that in our own (54 years) and the mean AHI somewhat higher (68/h and 55/h *vs* 35/h). Both studies, like our own, included unselected patients, *i.e.*, as far as possible all patients received nCPAP therapy until a defined date. In addition, our six local OSAS specialists, who were in effect blinded to the above studies, produced a remarkably similar mean DW (0.26), even if this is of limited robustness given the small sample.

Based on the available DW of 0.055 for NRSD,[3] these DW values for OSAS yielded a severity ratio of 4.2:1 to 4.7:1 for average-severity nCPAP-treatable OSAS to average-severity NRSD [Table 2]. However, the methods of determining the DW values differed. The values reported by Tousignant *et al.*[10] and Chakravorty *et al.*[21] were obtained using the standard gamble method,[20] which is an estimate performed from the patient's perspective. In the other cases, physicians derived the DW by interpolation into an existing disease DW matrix based on studies by the WHO[2] and Stouthard *et al.*[36] that mainly used time and person tradeoff techniques. Although both these techniques theoretically yield DW values identical to those of the standard gamble method, in practice, they turn out to be slightly higher.[37] An additional consideration is that the sick tend to attribute less disability to their disease than healthy subjects including health experts.[38] Such factors generate some uncertainty over calculating a severity ratio based on DW.

For this reason, we asked the 13 OSAS patients in our sample with experience of NRSD to rate the severity of each sleep disturbance. We then derived the ratio by dividing the OSAS VAS by the NRSD VAS. Since the start and endpoints were identical on both scales, the procedure was fundamentally legitimate, if not devoid of problems. Patients exposed simultaneously to OSAS and noise could have difficulty in assigning their symptoms. In theory, it should be possible because only nCPAP-treated OSAS patients were questioned, but in practice, it is uncertain how clearly they can differentiate the two forms of sleep disturbance. If, on the other hand, the NRSD rating is retrospective (by > 20 years in four patients), the memory of the noise is likely to have faded, yielding underestimated VAS ratings. Conversely, there is evidence that adverse events which affect a subject from the outside, without being directly his/her fault (e.g., noise), tend to attract a more negative rating than events caused by the subject or by fate (e.g., OSAS).[39] This results in an overestimated VAS rating for noise compared to OSAS. These two factors (chronological distance from the event and personal responsibility) thus, fortunately tend to shift the VAS rating for noise in opposite directions. We should however, also bear in mind that when woken by road traffic noise, patients consider it to have a greater direct impact on their sleep than OSAS, the main symptoms of which they experience the following day. Thus, patients could tend to rate NRSD higher than OSAS despite equal sleep disturbance. The mean VAS

ratio for OSAS/NRSD of 2.3:1 produced by our patients was markedly lower than the DW ratio of 4.2:1-4.7:1. Given these uncertainties and the small patient sample, we conclude that the VAS severity ratio for OSAS/NRSD should be used with caution.

Monetary equivalent for noise-related sleep disturbance

The resulting median ME for avoidance of average-severity nocturnal NRSD ranges from CHF 14.89 to CHF 30.43 per night [Table 2], depending on the severity ratio chosen. There is a high probability that the true ME lies between the lowest 25th percentile value (CHF 7.45) and the highest 75th percentile value (CHF 43.48). Given the methodological reservations in generating severity ratios between OSAS and NRSD, particularly those based on the VAS technique, we conclude that the ME for avoidance of NRSD lies between CHF 7.45 and CHF 23.81 per night [Table 2, rows 2 and 3]. This shows remarkable agreement with the ME of CHF 7 to CHF 41 per night obtained by Müller-Wenk and Hofstetter using a wide variety of methods.[4] However, as our study used benefit transfer between two forms of sleep disturbance instead of between widely disparate domains (*e.g.*, analysis of noisy and quiet home rents and WTP for avoidance of death risk),[4] its result can be termed more robust.

Conclusions

Our study produces the remarkable result that successfully treated OSAS patients in 2004, indicated a monetary value ME of 70 CHF (median) as an equivalent for a night with undisturbed sleep, which is several times higher than the actual cost (5 to 6 CHF per night) of the nCPAP therapy. This surprisingly high amount was chosen by the patients although the interviewer helped them calibrate the ME to the actual purchasing power of the CHF by stating that the average rent, heating costs included, for an apartment in the region amounted to 40 to 50 CHF per day. It would be desirable to verify this high appreciation of the nCPAP therapy by further studies.

Our study further showed that the participants reduced their ME valuation of 70 CHF by a factor of three, when they were asked how much they would spend if they had to pay the therapy from their own pocket. This is still much more than the actual cost of the therapy. However, it raises the question as to how people can express a best guess of their appreciation for an item or a service. The current mainstream thinking would say that actual market prices give the answer and WTP studies are a good method to simulate market behaviour. But is it acceptable that those who are financially unable to participate in the market have no full share of voice in this system of setting values? Our study demonstrates the large difference between attribution of value *per se* in the form of an ME and attribution of value by simulation of market situations in typical WTP studies. And even more interesting:

We could show that the patients' own severity rating on a VAS correlates to their monetary valuation in the form of ME, whilst their WTP values are clearly independent from the patients' VAS rating. In other words, the usual budget restriction of the WTP procedure prevented the patients from expressing their "true" values.

The severity comparison between OSAS-related sleep disturbance and noise-related sleep disturbance is complicated by the fact that each of the two types of sleep disturbance occurs in a broad spectrum of severity, whereby agreed definitions for low, medium and high severity are not yet available. Focusing on cases of mean severity on both sides, our study supplies a reasonably good evidence that NRSD is clearly less severe than OSAS-related sleep disturbance, but of the same order of magnitude. We therefore conclude that sleep disturbance due to traffic at night is an important impairment to public health and merits full attention of the medical and political communities.

Corresponding address:
Dr. Otto D. Schoch,
Kantonsspital St. Gallen, Rorschacherstrasse,
CH - 9007 St.Gallen, Switzerland.
E-mail: otto.schoch@kssg.ch

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