Assessment of Obstructive Sleep Apnea Risk and Severity in Truck Drivers: Validation of a Screening Questionnaire

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Abstract

Background: The prevalence of obstructive sleep apnea/hypopnea (OSA) in commercial truck drivers is substantially greater than in the general population and undiagnosed OSA in transportation workers is a concern. We describe the validation of a simple, inexpensive and easy to use screening tool to identify individuals with a significant probability of OSA.

Methods: Six-hundred and eight subjects completed the Apnea Risk Evaluation System (ARES) sleep apnea screening questionnaire to develop and validate an algorithm for assigning a risk of having OSA. Individuals were assigned as having "No Significant Risk", "Low Risk" or "High Risk" of OSA; 469 of these subjects completed overnight polysomnography. A second, independent group of 850 subjects also completed the ARES questionnaire and thereafter completed an in-home sleep study (> 4 hours) with the ARES Unicorder to develop an algorithm for predicting OSA severity based on questionnaire responses. A third, independent data set of ARES Questionnaire responses were obtained from 100 transportation workers. Twenty classified as "High Risk" of OSA successfully completed ARES sleep studies. The prevalence of OSA among the transportation workers was computed based on OSA risk and OSA severity.

Results: The Questionnaire analysis provided a sensitivity of 0.94 and a specificity of 0.79 for an apnea/hypopnea index (AHI) > 5. Fifty-three percent of the transportation workers were identified as being at "high risk" of OSA and 77% of them predicted to have Severe OSA had an AHI > 20.

Conclusions: The ARES Questionnaire analysis provided a high sensitivity in identifying patients with OSA while limiting the economic cost of false-positive results (i.e., portion of true-negative individuals who were classified as at-risk by questionnaire). The OSA severity prediction proved effective in stratifying patients into different categories that may be useful in triaging patients for follow-up diagnostic testing.

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Indroduction

Between 10% to 50% of motor vehicle accidents are attributed to sleepiness - more U.S. freeway fatalities are caused by fatigue than alcohol or drugs,[1,2] Obstructive Sleep Apnea and/or Hypopnea (OSA) contributes to this national safety concern because it causes somnolence and performance impairment.[3] Untreated OSA patients are 3-7 times more likely to be involved in industrial and motor vehicle accidents and have demonstrably slower reaction times and impaired performance on tests of vigilance, memory and executive functions.[2,4–9] In most cases these impairments are reversible following successful treatment with Continuous Positive Airway Pressure (CPAP) systems or Mandibular Advancement Devices.[10]

Commercial truck and bus drivers are at even greater risk for OSA than the general population[11–14] because they are predominantly middle-aged men with increased prevalence of obesity and hypertension—important risk factors for OSA. Irregular sleep schedules with concomitant sleep deprivation in long-haul drivers may also exacerbate sleep-disordered breathing.[15] The U.S. Department of Transportation (DOT) Task Force on Pulmonary Disorders and Commercial Drivers[15] identified untreated OSA as an important preventable cause of motor vehicle accidents.

The DOT mandates physical exams be conducted every two years to certify that commercial vehicle drivers are medically fit for duty. The original guidelines provided by experts in pulmonology to the Federal Motor Carrier Safety Administration (FMCSA) on OSA and driver fitness for duty dates back to 1991, and suggested that drivers with OSA were not medically qualified for vehicle operation until the OSA was adequately treated.[16] A diagnosis of OSA was recommended when a driver had 30 or more abnormal breathing episodes per hour of sleep (a Respiratory Disturbance Index (RDI) ≥ 30) or hypersomnolence during waking hours associated with apneic activity greater than 5 episodes per hour. Approximately two years ago, the FMCSA added four questions to the medical examination reporting form asking the driver whether he/she: 1) had a sleep disorder, 2) was a loud snorer, 3) had daytime sleepiness, or 4) stopped breathing during sleep. In 2006, a joint task force

of the American College of Chest Physicians, American College of Occupational and Environmental Medicine and the National Sleep Foundation provided updated recommendations for Sleep Apnea and Commercial Motor Vehicle Operators ("Joint Task Force Recommendations").[17] The recommendations include specific screening guidelines including when to designate a driver, diagnosed with OSA, as medically qualified for work. A bill recently introduced in the New York State Legislature followed the recommendation of the joint task force, mandating that all drivers at high risk for OSA be tested at the time of the driver's biannual fitness for duty physical. The bill also requires the holders of commercial license to be tested for OSA within two-weeks of an accident.[18]

There have been two published studies on the prevalence of OSA among U.S. commercial drivers. The first, conducted by Stoohs et al., published in 1995, studied 388 drivers employed by a large U.S. trucking firm.[14] The results were unprecedented, in that 78% of the drivers had a RDI above the normal (RDI ≥ 5) and 46% had an RDI ≥ 10. The second study by Pack and Maislin, published in 2006, in a regional random sample of 1,391 commercial drivers reported only 17.6% of the drivers with mild OSA.[19] The discrepancy in the prevalence of OSA among commercial drivers in these two studies is substantial, and likely resulted from the different methods employed. In the Stoohs et al. study, all drivers at a loading hub completed a questionnaire, with 91% agreeing to undergo monitoring. About 10 years later, in the study by Pack and Maislin, fewer than 30% of the commercial drivers returned responses, and less than 10% of those that responded were selected to participate in the study – perhaps suggesting a response bias in favor of those without symptoms of OSA given increased driver awareness about OSA coupled with uncertainty about how an OSA diagnosis might affect their livelihood.

In the years since these two studies were completed it has become increasingly difficult to recruit new drivers. As the commercial driver population continues to get older, the prevalence of OSA among drivers is expected to increase.

Our goal was to develop and validate the Apnea Risk Evaluation System (ARES™) Questionnaire as a tool to: a) identify those at risk for OSA who need a sleep study, and b) predict OSA severity that might be useful in triaging "at-risk" individuals.

Methods

Screening Questionnaire: The ARES Questionnaire (Figure 1) is one page in length, and can be filled out by the patient in less than five minutes without assistance. Data obtained include age, gender, height, weight and neck size, diagnosis of diseases associated with risk for OSA (i.e., high blood pressure, heart disease, diabetes, or stroke) or prior diagnosis of OSA, the Epworth Sleepiness Scale and a five-scale response to the frequency rating for snoring, waking up choking and having been told that he/she stopped breathing during sleep (0 = never, 1 = rarely – 0-1 times/wk), 2 = sometimes (1-2 times/wk), 3 = frequently – 3-4 times/wk, and 4 = almost always – 5-7 times/wk). The questionnaire is available in several languages, e.g., Spanish, French, etc.. The ARES software (Advanced Brain Monitoring, Carlsbad, CA) allows easy input of questionnaire responses using an inexpensive, desktop scanner with the result immediately computed, presented and written to a database.

Assigning OSA risk: An algorithm to assign an OSA risk was developed and validated using a data set of 608 participants. Data were acquired as part of four NIH funded research studies, and all participants provided informed consent under the auspices of the BioMed IRB (San Diego, CA). The participants included 479 patients who provided ARES Questionnaire responses and underwent full laboratory-based polysomnography (PSG). These included 369 individuals who had been referred to a sleep clinic for evaluation of presumptive OSA, 56 were general medical patients (i.e., diagnosed with hypertension or cardiovascular disease) and 54 were presumably healthy controls. PSGs were acquired at six sleep disorders centers, and scored according to the American Academy of Sleep Medicine (AASM) criteria.[20] An additional 129 presumed healthy community-based individuals were screened with an extensive medical history questionnaire and assumed not to have OSA (< 5 events/hour) but the absence of OSA was not confirmed by PSG. The characteristics of these four groups are presented in Table 1.

The patient data from those referred for PSG were split into a model development and supplemental group. Subjects in this model development group were assigned to either the OSA group (AHI > 5 events/hr) or healthy controls (AHI < 5 events/hr). Stepwise analysis (SAS, Cary, NC) was used to select the variables most predictive in discriminating between the two groups. The variables selected by this analysis and the R^2 are presented in Table 1. Two-class discriminant function equations were developed to assign each set of responses into either "high risk" or "no apparent risk" categories.

A third category, called "low risk", was developed to recognize individuals otherwise classified as "no apparent risk" but with historically important independent risk factors for OSA.[21] These risk factors included: the diagnosis of high blood pressure, heart disease, diabetes, or stroke; those who answered always to snoring frequency, waking up choking, and/or told he/she stops breathing during sleep; or had both a body mass index (BMI) greater than 31.5 and a neck size greater than 43.2 cm (17.0 inches) for males or 39.4 cm (15.5 inches) for females.

Predicting OSA Severity: A second, independent data set was used to develop an algorithm for predicting OSA severity in individuals assigned to the "high risk" category (Table 2). The OSA severity algorithm was developed using a database of 850 subjects (584 males and 266 females) who had completed an in-home diagnostic study and had a minimum valid recording time of 4-hours. The BioMed IRB (San Diego, CA) approved a retrospective review of patient data obtained from subjects who had undergone diagnostic sleep studies and were included in a database.

All patients completed a diagnostic study used the ARES Unicorder™. From a single site on the forehead, the wireless Unicorder records oxygen saturation, pulse rate, airflow, respiratory effort , snoring levels, head movement and head position.[22] Automated scoring algorithms are applied to the acquired signals to characterize four apnea/hypopnea index criteria which differ primarily on the depth of the desaturation. To characterize OSA approximately equivalent to the AASM criteria,[20] the auto-scoring algorithms identified apneas (based on 10-second cessation in airflow) and hypopneas based on a 50% change in airflow plus a minimum desaturation and resaturation, and at least one surrogate arousal indicator (using changes in snoring patterns, pulse rate and/or head movement). The minimum desaturation/resaturation depends on the SpO2

ARES™ Screener Questionnaire ©

PLEASE ANSWER ALL QUESTIONS

First Name	Middle Initial	Last Name

Neck Circumference	Inches	**Age**	Years	**Male** ☐	**Female** ☐
Height	Feet	Inches		**Weight**	Pounds
Date of Birth	Month /	Day /	Year	**ID Number** (optional)	

Have you been diagnosed or treated for any of the following conditions?					
High Blood Pressure	Yes ☐	No ☐	Currently Pregnant	Yes ☐	No ☐
Heart Disease	Yes ☐	No ☐	Sleep Apnea	Yes ☐	No ☐
Diabetes	Yes ☐	No ☐	Nasal or Mask Oxygen Use	Yes ☐	No ☐
Stroke	Yes ☐	No ☐			

Epworth Sleepiness Scale: How likely are you to doze off or fall asleep in the following situations, in contrast to just feeling tired? This refers to your usual way of life in recent times. Even if you have not done some of these things recently, try to work out how they would have affected you. Use the following scale to circle the most appropriate number for each situation. (M.W. Johns, Sleep 1991)

0 = would never doze **1** = slight chance of dozing **2** = moderate chance of dozing **3** = high chance of dozing

	0	**1**	**2**	**3**
Sitting and reading	☐	☐	☐	☐
Watching TV	☐	☐	☐	☐
Sitting, inactive, in a public place (theater, meeting, etc)	☐	☐	☐	☐
As a passenger in a car for an hour without a break	☐	☐	☐	☐
Lying down to rest in the afternoon when circumstances permit	☐	☐	☐	☐
Sitting and talking to someone	☐	☐	☐	☐
Sitting quietly after lunch without alcohol	☐	☐	☐	☐
In a car, while stopped for a few minutes in traffic	☐	☐	☐	☐

On average in the past month, how often have you snored or been told that you snored?				
Never ☐	Rarely ☐ 0-1 times/week	Sometimes ☐ 1-2 times/week	Frequently ☐ 3-4 times/week	Almost always ☐ 5-7 times/week
Do you wake up choking or gasping?				
Never ☐	Rarely ☐ 0-1 times/week	Sometimes ☐ 1-2 times/week	Frequently ☐ 3-4 times/week	Almost always ☐ 5-7 times/week
Have you been told that you stop breathing in your sleep or wake up choking or gasping?				
Never ☐	Rarely ☐ 0-1 times/week	Sometimes ☐ 1-2 times/week	Frequently ☐ 3-4 times/week	Almost always ☐ 5-7 times/week

Phone: _____ Home Cell Work (Please Circle One)

Patient Signature: _____ Date: _____

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Fig. 1. Screener Questionnaire.

Table 1. Characteristics of the Groups Used to Assess the Accuracy of the OSA Risk Algorithm

Variables used to predict OSA Risk	R^2	*Model Development. Referred for PSG*	*General Medical*	*Presumed Healthy*	*Supplemental Referred for PSG*
Male, n (%)	0.04	150 (65.2)	32 (57.1)	94 (51.4)	91 (65.5)
Female, n (%)	0.04	80 (34.8)	24 (42.9)	89 (48.6)	48 (34.5)
Mean age ± S.D, years	0.09	48.6 ± 10.9	54.0 ± 11.0	42.2 ± 11.2	47.6 ± 10.7
Mean BMI ± SD, kg/m^2	0.31	32.8 ± 6.8	34.4 ± 8.1	24.6 ± 3.7	35.0 ± 8.3
Mean neck size ± SD, cm	0.29	42.4 ± 4.6	42.6 ± 5.3	36.7 ± 4.2	42.5 ± 5.1
High blood pressure, yes (%)	0.15	83 (36.1)	46 (82.1)	0 (0/0)	59 (42.5)
Mean Epworth score ± SD	0.13	11.7 ± 5.4	8.9 ± 4.3	6.5 ± 4.5	11.8 ± 1.2
Mean snoring ± SD*	0.36	3.4 ± 0.9	2.5 ± 1.3	1.4 ± 1.2	3.6 ± 0.7
Mean wake up choking ± SD*	0.16	1.6 ± 1.2	1.0 ± 1.2	0.2 ± 0.6	1.8 ± 1.2
Mean told stop breathing ± SD*	0.24	1.9 ± 1.3	0.9 ± 1.1	0.3 ± 0.8	2.5 ± 1.4

* 0 = never, 1 = rarely, 2 = sometimes, 3 = frequently, and 4 = almost always

Table 2. Characteristics of the Groups Used to Develop and Cross Validate the Prediction of OSA Severity by Questionnaire

Population Characteristics	*Model Development Group*	*Transportation Workers Pre-hires*	*Managers*
Male, n (%)	584 (68.7)	52 (100.0)	48 (100.0)
Female, n (%)	266 (31.3)	0 (0.0)	0 (0.0)
Mean age ± S.D, years	51.7 ± 12.0	37.7 ± 10.4	44.6 ± 9.1
Mean BMI ± SD, kg/m^2	32.4 ± 6.9	30.5 ± 5.3	30.8 ± 5.3
Mean neck size ± SD, cm	42.6 ± 4.3	43.0 ± 3.5	43.7 ± 3.4
Disease (e.g. HBP), yes (%)	622 (65.8)	6 (11.5)	9 (18.8)
Mean Epworth score ± SD	9.9 ± 5.2	4.3 ± 3.6	7.3 ± 4.7
Mean snoring ± SD*	3.2 ± 1.1	1.3 ± 1.1	2.0 ± 1.5
Mean wake up choking ± SD*	1.2 ± 1.2	0.1 ± 0.2	0.5 ± 1.0
Mean told stop breathing ± SD*	1.5 ± 1.4	0.1 ± 0.3	0.6 ± 1.0

* 0 = never, 1 = rarely, 2 = sometimes, 3 = frequently, and 4 = almost always

level at the beginning of the OSA event; 1% is required if the baseline SpO2 is > 93% and 1.2% if the baseline is > 91% but < 93%.

Step-wise regression analyses were conducted with different combinations of ARES Questionnaire responses which balanced maximum prediction (R^2) with the least variables. The variables which provided the optimal regression equation included: body mass index, Epworth Sleepiness Score, neck size, total number of co-morbid diseases (out of a maximum of 4), and the five-scale rating for "snoring", "waking up choking" and "told that he/she stopped breathing during sleep." Gender specific predictive algorithms were found to be most accurate and used in all further analyses.

From the appropriate gender-based algorithm, multiple linear regressions generated predicted-Apnea/Hypopnea Index values. Probability distribution estimates based on normality assumptions (i.e., similar to confidence interval estimates) were calculated for each set of responses in order to determine the probability of correctly assigning the predicted-AHI into each of four severity categories The OSA severity categories were based on AHI ranges recommended by the American Society of Anesthesiologists,[23] i.e., Severe (AHI > 40), Moderate (AHI 21 – 40), Mild (AHI 6 – 20) and Minimal (AHI < 5). The OSA severity assigned to a given set of responses was based on the largest of the four probabilities, where there was a tie between probabilities, the more severe OSA category was assigned.

Assessing OSA prevalence in Transportation Workers: A group of 48 male service center managers in Southern California completed the ARES Questionnaire. Twenty-four managers identified as "high risk" for OSA and were provided an opportunity to complete an ARES home sleep recording. Twenty managers acquired a minimum of 2.5 hours of valid record time and four did not attempt an ARES study.

A total of 52 drivers completed the Questionnaire at the time of hire at three service regions: Southeast (Atlanta, GA), Southwest (Dallas, TX) and Southern California. The distributions of the Questionnaire responses for these transportation workers are also presented in Table 2. The BioMed IRB (San Diego, CA) approved a retrospective review of these worker's data.

Results

Assigning OSA risk: Data from 608 subjects described in Table 1 were used to assess the accuracy of the assignment of OSA risk. The Questionnaire analysis yielded a sensitivity of 0.94, specificity of 0.79 (based on a clinical cut-off of AHI > 5), positive predictive value of 0.91 and negative predictive value of 0.86 with individuals classified as "low risk" were considered negative for OSA (see Table 3).

Assigning OSA severity: Figure 2 presents the distributions of AHI sleep study results stratified by OSA severity based on the ARES questionnaire for 850 subjects: 42% of individuals

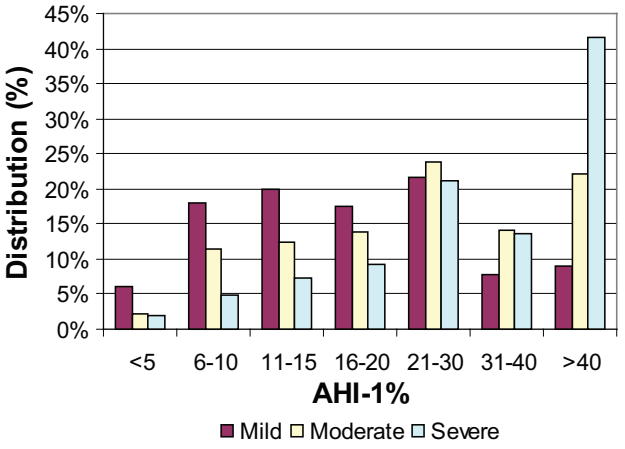

Fig. 2. Distribution of patients (n = 850) assigned into OSA severity categories, stratified by AHIs obtained from sleep studies.

Table 3. Classification Statistics of the OSA Risk Analysis

Statistical Category	*AHI > 5*	*95% Conf. Interval*	
Sensitivity	0.94	0. 92	0.95
Specificity	0.79	0.75	0.82
Positive Predictive Value	0.91	0.89	0.92
Negative Predictive Value	0.86	0.81	0.89
Positive Likelihood Ratio	4.4	3.6	5.4

Table 4. Pretest and Posttest Probabilities for Cases Classified with "No Apparent Risk" of OSA Based on the Expected Distributions of Apnea/Hypopnea Indexes (AHI)

	No Significant Risk		
AHI	*Pretest Prob.*	*Posttest Prob.*	*(95% CI)*
<5	0.90	0.98	(0.97–0.98)
6 – 20	0.09	0.30	(0.26–0.35)
21 – 40	0.01	0.03	(0.02–0.04)
>40	0.00	0.00	(0.00–0.00)

assigned to the severe OSA category were found on PSG to have an AHI > 40, 77% had an AHI >20, and only 2% had an AHI < 5; 22% considered at risk of moderate OSA had an AHI > 40, while 60% had an AHI >20, and 2% had an AHI < 5. Only 8% of individuals assigned to the mild OSA risk category had an AHI > 40, 37% had an AHI >20, and 5% had an AHI < 5.

From the distribution of AHIs in those classified as "no apparent risk" for the dataset presented in Table 1, the pretest probability for false negatives by the ARES Questionnaire was evaluated. The posttest probabilities presented in Table 4 were computed using the pretest odds (pretest probability/1 – pretest probability) multiplied by the positive likelihood ratios presented in Table 3 and conversion from posttest odds to posttest probability (posttest odds/1 + posttest odds). Although the sensitivity of the Questionnaire would result in a false-negative rate of 6%, the probability of a patient having a posttest AHI > 20 is only 3%.

Table 5 presents the data used in Figure 2, collapsed into four AHI ranges, with the associated pretest probability of having OSA in individuals predicted by questionnaire analysis to have Mild, Moderate and Severe OSA. The posttest probabilities were computed using the pretest odds (pretest probability/ 1 – pretest probability) multiplied by the positive likelihood ratios presented in Table 3 and conversion from posttest odds to posttest probability (posttest odds / 1+posttest odds). Pretest and posttest probabilities are assigned for each discrete AHI range.

Assessing OSA prevalence in Transportation Workers: The prevalence of "no apparent risk" of OSA was 27% in the managers and 44% in the pre-hires. The prevalence of "high risk" of OSA was 63% in managers and 44% in pre-hires. The distributions of OSA Severities across the combined groups are presented in Figure 3. Of those classified as "high risk" for OSA, 42% were predicted to have severe OSA.

All 20 of the transportation workers classified at "High Risk" by Questionnaire and who completed a sleep study had an AHI > 5. Of those predicted to have moderate OSA, 40% had an AHI > 20 and 20% had an AHI > 40. Of those predicted to have severe OSA, 77% had an AHI > 20 and 39% had an AHI > 40.

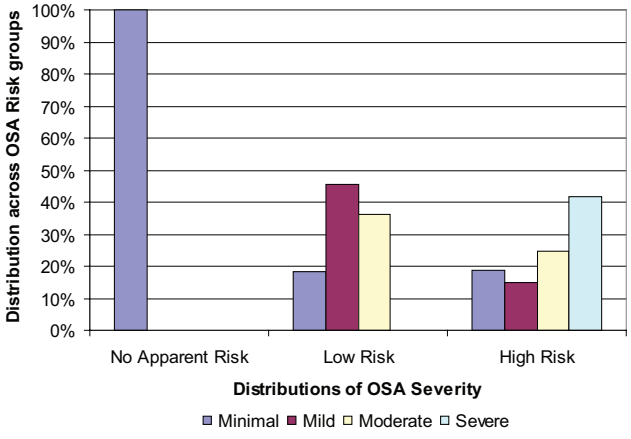

Fig. 3. Distribution of predicted OSA severity for transportation workers classified with No Apparent Risk, Low Risk and High of OSA.

Discussion

For a typical screening tool, sensitivity is the most important accuracy criteria. However, to convince employers to screen for OSA, specificity is also important because of the costs associated with false positive cases. The ARES algorithm for assigning OSA risk provided a sensitivity and specificity of 94% and 79% respectively.

These results are an improvement over the Berlin Questionnaire which reported a sensitivity and specificity of 0.86 and 0.77 using the same clinical cut-off for predicting an RDI greater than 5.[24] Both surveys utilized similar demographic and anthropomorphic data. The Berlin Questionnaire asks about high blood pressure while the ARES Questionnaire includes heart disease, diabetes, stroke and prior diagnosis of OSA. The Berlin Questionnaire includes nine additional questions while the ARES Questionnaire includes the Epworth Sleepiness Score and three additional questions. With any questionnaire there is a trade off between its length and the predictive

Table 5. Pretest and Posttest Probabilities for the Predicted OSA Severity in 850 Subjects Based on the Apnea/Hypopnea Index (AHI) Obtained from Sleep Studies Conducted In-Home

	Identified with High Risk of OSA with an OSA Severity of								
	Mild			*Moderate*			*Severe*		
AHI	*Pretest Prob.*	*Posttest Prob.*	*(95% CI)*	*Pretest Prob.*	*Posttest Prob.*	*(95% CI)*	*Pretest Prob.*	*Posttest Prob.*	*(95% CI)*
<5	0.06	0.22	(0.19–0.26)	0.02	0.10	(0.08–0.12)	0.02	0.07	(0.05–0.08)
6 – 20	0.56	0.85	(0.82–0.87)	0.38	0.73	(0.67–0.77)	0.22	0.56	(0.49–0.61)
21 – 40	0.29	065	(0.60–0.69)	0.38	0.73	(0.67–0.77)	0.35	0.70	(0.64–0.75)
> 40	0.09	0.29	(0.25–0.34)	0.22	0.55	(0.48–0.60)	0.41	0.75	(0.69–0.79)

value. An abbreviated version of the Berlin Questionnaire, which reduced the number of questions to four, resulted in 50% fewer patients being identified at high risk.[25]

The ARES Questionnaire analysis was slightly less accurate than the neural network-based OSA predictor developed by Kirby et al.[26] That study demonstrated a sensitivity of 98.9% and a specificity of 80% in 405 patients referred for a PSG. The differences in accuracy between the two models may relate to the fact that 39% of the subjects used to validate the OSA risk in our study were recruited from the community and not limited to those referred for possible OSA. While the OSA risk analysis method in the study by Kirby et al. was validated in a population that included 28% females; the population in this study for the ARES OSA risk analysis included 35% females. Ultimately, the validation of any screening tool needs to be made in the population to which it will be applied.

Predicting OSA severity from questionnaire responses provided similar likelihood ratios to those derived by the statistical approach reported by Flemons et al.[21] Predicting the probability of OSA can be used to help triage individuals who have the greatest risk. In this study, the predicted OSA severities were from a database of over 850 cases (vs. 180) and greater resolution of the distribution of AHIs was provided.

For cases classified with "no apparent risk", the posttest probability of having an AHI greater than 20 was only 3%, whereas the posttest probability of having an AHI between 6 and 20 when categorized on Questionnaire data as "mild" was 87%. When categorized as "severe", the posttest probability of having an AHI greater than 20 was 70%. The posttest probability increased to 75% when a clinical cut-off of AHI > 40 was applied.

The inclusion of confidence interval estimates for each response gave a unique distribution of probabilities across the four OSA severity categories. Frequency of snoring, for example, is an excellent predictor of those who may have an AHI > 5 events / hr, but because it is similarly distributed across all four OSA severity groups it does little to identify those with mild vs. severe OSA. Thus, the definitiveness of the OSA severity classification is influenced by the number and distribution of risk factors.

The ARES Questionnaire analysis effectively identified transportation workers with sleep disordered breathing. Using the AASM criteria (i.e., ARES-AHI-1%) and a clinical cut-off of 5, all workers identified at High Risk were correctly found to have undiagnosed sleep disordered breathing. The data from this study on OSA prevalence in transportation workers more closely paralleled those reported by Stoohs et al.[14] than those reported by Pack and Maislin.[19]

This study has several limitations. One was that the responses used to develop the OSA risk analysis were not used to cross-validate the OSA severity algorithm because ARES sleep study data were not available. Another limitation was that the estimate of the system's specificity included a subgroup of controls who did not undergo a confirmatory sleep study. Additional sleep studies should be performed on a community based group of presumably healthy controls in order to reduce the estimation error attributed to the specificity of the measurement tool. In spite of our efforts, a third limitation was that age and gender were not matched in the healthy vs. disease groups used to develop the OSA risk algorithm, reflecting the known bias in OSA patient populations. A fourth limitation was that transportation workers classified as "No Apparent" risk or "Low" risk did not undergo a sleep study so the specificity of the Questionnaire in this population could not be assessed.

The sleep study data used to develop the OSA severity algorithm and to predict the prevalence of OSA was obtained using a limited-channel portable monitoring system and automated scoring algorithms. The reduced cost associated with a portable sleep studies combined with the flexibility to study transportation workers in their home or truck sleeper compartment may be an advantage in this population where the prevalence of undiagnosed OSA is high and the work schedule is unpredictable. The legal issues relating to this study of commercial drivers is discussed in the follow-up commentary to this paper.

The ARES is one of several new portable devices introduced and validated subsequent to the review by Flemons et al[27] in which it was concluded that there was insufficient evidence to support the use of portable monitoring over laboratory PSG. More recently, a study concluded that laboratory PSG provides no advantage to an ambulatory approach in terms of diagnosis and CPAP titration in patients with a high probability of OSA.[28] The Questionnaire analysis validated in this paper provides a simple and inexpensive means to identifying those with a high probability of having OSA.

Conclusions

The ARES Questionnaire as a screening tool for OSA was found to have high sensitivity. 0.94. in identifying patients with OSA with a specificity of 0.79 for correctly identifying individuals without OSA. As a fast, easy to administer, and inexpensive

means to screen patients at risk for OSA the ARES Questionnaire could be especially beneficial in the transportation industry given the confirmed prevalence of the disease in this population. The OSA severity prediction proved effective in stratifying patients into different categories. This capability is suitable in situations where the population has a large pretest probability of OSA and where there are only limited resources that can be applied to individuals suspected of having some level of risk (i.e., commercial drivers or perioperative risk management). When used in these situations, the Questionnaire analysis can assist clinicians allocate resources to those with the greatest likelihood of having severe OSA, so that those in more urgent need of care are adequately provided for.

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