

SCIENTIFIC INVESTIGATIONS

Cost-Effectiveness of Split-Night Polysomnography and Home Studies in the Evaluation of Obstructive Sleep Apnea Syndrome

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Study Objectives: Split-night polysomnography (PSG) and unattended home sleep studies have come into use as less-expensive tests for obstructive sleep apnea syndrome, but their impact on cost-effectiveness of the overall evaluation and treatment is unknown. We compared the cost-effectiveness of evaluations that employ these 2 procedures with a conventional approach using full-night PSG.

Methods: We used a decision-tree model that incorporated typical clinical algorithms for each of the 3 strategies to compare their cost-effectiveness from a third-party payer perspective over a 5-year period. Probabilities and test characteristics were derived from data from the published literature. Cost estimates were based on the 2004 Medicare Fee Schedule. Survival rates were taken from National Center for Health Statistics data and published studies. Effectiveness was measured as quality-adjusted life years.

Results: Trade-offs of overall costs versus effectiveness were identified. The home-studies strategy was less costly and less effective than split-night PSG and full-night PSG, as was split-night PSG compared with

full-night PSG. Costs to attain additional quality-adjusted life years were below commonly accepted thresholds. A probabilistic analysis suggested that the home-studies approach was most cost-effective at the lowest amounts of third-party willingness to pay, whereas split-night PSG or full-night PSG was most cost-effective at higher amounts.

Conclusions: Home studies and split-night PSG are cost-effective alternatives to full-night PSG. Willingness-to-pay is an important consideration in choosing the most cost-effective approach. This study points out the importance of considering the complexities within the entire process of obstructive sleep apnea syndrome evaluation when comparing costs among different procedures.

Keywords: Obstructive sleep apnea, cost-effective analysis, polysomnography

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Obstructive sleep apnea syndrome (OSAS) is a major health problem associated with impaired quality of life, cardiovascular complications, and higher accident risk.¹ The economic implications of OSAS have received considerable attention because of its high prevalence^{1,2} and enormous consumption of healthcare services by persons with untreated OSAS.^{3,4}

Treatment of OSAS by continuous positive airway pressure (CPAP) is beneficial and cost-effective⁵⁻⁷ but requires careful medical decision making based on diagnostic testing and titration to an optimal CPAP level. The conventional approach, full-night polysomnography (PSG) and CPAP titration during 2 overnight stays in a sleep laboratory (full-night PSG)⁸ has been costly and may present scheduling difficulties when there is high demand. Other approaches considered for their potential to reduce costs

and increase accessibility include split-night PSG,⁹⁻¹³ unattended home partial sleep monitoring (UHPSM),¹⁴⁻²⁰ and home CPAP titration using an autotitrating device (CPAP autotitration).²¹⁻²⁴ Validation of the accuracy and effectiveness of these alternative approaches to planning treatment has been the subject of numerous studies.⁹⁻²⁷

Commentary Follows on Pages 154-155

Split-night PSG is an attended, in-laboratory, overnight procedure during which sleep and breathing variables are recorded during the first 2 hours of the sleep period, and, if criteria are met,⁸ CPAP titration is performed during the remainder of the night. Split-night PSG may provide diagnostic effectiveness comparable with that of full-night PSG for patients who demonstrate frequent obstructive events in the early sleep period.^{9-13,25,26} However, concern has been raised about insufficient diagnostic sampling and inadequate time for CPAP titration.¹² Studies comparing the cost-effectiveness of split-night PSG with other modalities for OSAS diagnosis and CPAP titration have not been reported.

In contrast to full-night PSG and split-night PSG, UHPSM is not attended by a technician and does not include electroencephalographic tracings, raising uncertainty about when tracings are actually recorded during sleep. It has been promoted as a means of reducing costs in the evaluation of OSAS but is less accurate than full-night PSG and split-night PSG and is susceptible to data

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loss.¹⁴⁻²⁰ Cost-effectiveness studies have suggested that, although UPHSM studies are less expensive than full-night PSG, evaluations using full-night PSG have greater value per dollar spent²⁸ and lower overall process costs.²⁹

CPAP autotitration has been introduced as an unattended method to determine optimal CPAP settings.²¹⁻²⁴ Autotitrating devices provide continuous self-adjustment and recording of CPAP requirements during a single overnight session or nightly for a period of several days to weeks. CPAP autotitration is typically used after documentation and grading of OSAS by either PSG or UPHSM. A combination of UPHSM and CPAP autotitration can be used to accomplish both OSAS diagnosis and CPAP titration in the home.²⁰

We developed a decision-tree model to compare the cost-effectiveness of 2 potentially cost-saving strategies, split-night PSG and home studies (UHPSM and CPAP autotitration) with conventional full-night PSG. Our research aims were to gain insight into how these approaches compare in terms of costs and health benefits and to better understand the factors that influence cost-effectiveness in the assessment of OSAS.

METHODS

This study targeted a hypothetical cohort of persons aged 30 to 64 years of whom 85% were men. All had symptoms highly suggestive of OSAS, specifically, excessive daytime somnolence, persistent snoring, and witnessed apneas during sleep.

Decision Tree Model

A decision tree (Figure 1) was constructed in TreeAge Pro Suite (TreeAge Software, Inc, Williamstown, MA) to model the process of an OSAS diagnostic evaluation followed by CPAP titration using full-night PSG, split-night PSG, or home studies. For full-night PSG and split-night PSG, an apnea-hypopnea index of 10 or greater⁸ or, for UHPSM, a respiratory disturbance index of 10 or greater¹⁴⁻¹⁸ was required for a diagnosis of OSAS. It was assumed that, in this highly symptomatic cohort, treatment would be considered for all patients who met these criteria.

Published CPAP acceptance rates suggest a relation to the method of CPAP titration used.^{20,25-27,30-34} Some reports have noted that some patients do not return for PSG after a nondiagnostic home sleep study.^{16,20,24} Therefore, the model took into consideration conditions of pathway-specific CPAP acceptance and dropouts. This analysis assumed that patients who dropped out remained undiagnosed and untreated.

Time Horizon

The analytical time horizon used was 5 years, consistent with the period over which data regarding long-term CPAP compliance³⁰⁻³⁴ is currently available. Previous cost-effectiveness studies that have analyzed the diagnostic approach to OSAS and value of CPAP^{5,28} have also examined a 5-year period.

Probabilities and Test Characteristics

Probabilities, sensitivities, and specificities of diagnostic tests were based on published data from study populations similar to our cohort (Table 1). When published data suggested more than 1 probability, a mean value weighted by sample size was used.

Table 1—Model Assumptions

| Variable | Value Chosen* | Range in the Published References | Published References |
|---|---------------|-----------------------------------|----------------------|
| Chance Node Probabilities | | | |
| OSAS pretest probability | 0.82 | 0.79-0.85 | 9,19,28 |
| PSG sensitivity | 0.97 | — | 35,36 |
| PSG specificity | 1.00 | — | 35,36 |
| CPAP accepted | | | |
| Full-Night PSG | 0.93 | 0.88-0.98 | 31-34 |
| Split-Night PSG | 0.89 | 0.80-0.93 | 25-27 |
| UHPSM | 0.86 | — | 20 |
| Split-night PSG specificity | 0.90 | 0.70-1.00 | 9,10 |
| Split-Night PSG sensitivity after first 2 h | 0.93 | 0.90-0.96 | 9,27 |
| Second night needed for CPAP titration after OSAS documented in first 2 h | 0.18 | 0.10-0.20 | 11,13,26,27 |
| Satisfactory UHPSM | 0.80 | 0.67-0.82 | 16-20 |
| UHPSM sensitivity | 0.95 | 0.90-0.95 | 15,17,18 |
| UHPSM specificity | 0.73 | 0.70-0.96 | 15,17,18 |
| PSG follow-up after negative or unsuccessful home study procedure | 0.77 | — | 20 |
| CPAP autotitration unsuccessful for patient with OSAS | 0.13 | — | 23 |
| Cost Estimates | | | |
| Full-Night PSG (CPT 95810) | \$788.00 | — | † |
| Polysomnographic CPAP titration (CPT 95811) | \$852.00 | — | † |
| Split-night PSG (CPT95811) | \$852.00 | — | † |
| UHPSM (CPT 95806) | \$218.00 | — | † |
| CPAP autotitration (CPT95806) | \$218.00 | — | † |
| CPAP rental and accessories | | | |
| Year 1 | \$1600.00 | — | † |
| Year 2 | \$821.00 | — | † |
| Years 3-5 | \$700.00 | — | † |
| Office visits (CPT 99214) | \$89.81 | — | † |
| Utilities | | | |
| OSAS treated | 0.55 | 0.55-0.87 | 6,7 |
| OSAS untreated | 0.32 | 0.32-0.63 | 6,7 |
| No OSAS | 0.435‡ | 0.435-0.75 | 6,7,28 |
| No OSAS treated | 0.32‡ | 0.32-0.63 | 6,7,28 |

OSAS refers to obstructive sleep apnea syndrome; PSG, polysomnography; CPAP, continuous positive airway pressure; UHPSM, unattended home partial sleep monitoring; CPT, Current Procedural Terminology code.

*Value chosen from references.

†Data from the 2004 Medicare Fee Schedule.

‡From the estimates of Chervin.²⁸

Some probabilities required reconciliation to the OSAS pretest probability to allow internal consistency of the proportion of patients with OSAS by each pathway and were calculated as explicit functions of the pretest probability and published values for sensitivity and specificity.

An OSAS pretest probability of 82% was selected to be consistent with published studies that provided the chance-node values.^{9,13,19,28} The pretest probability is determined by the case mix among patients selected for OSAS evaluation. This analysis targeted a population at moderate to high risk for OSAS.

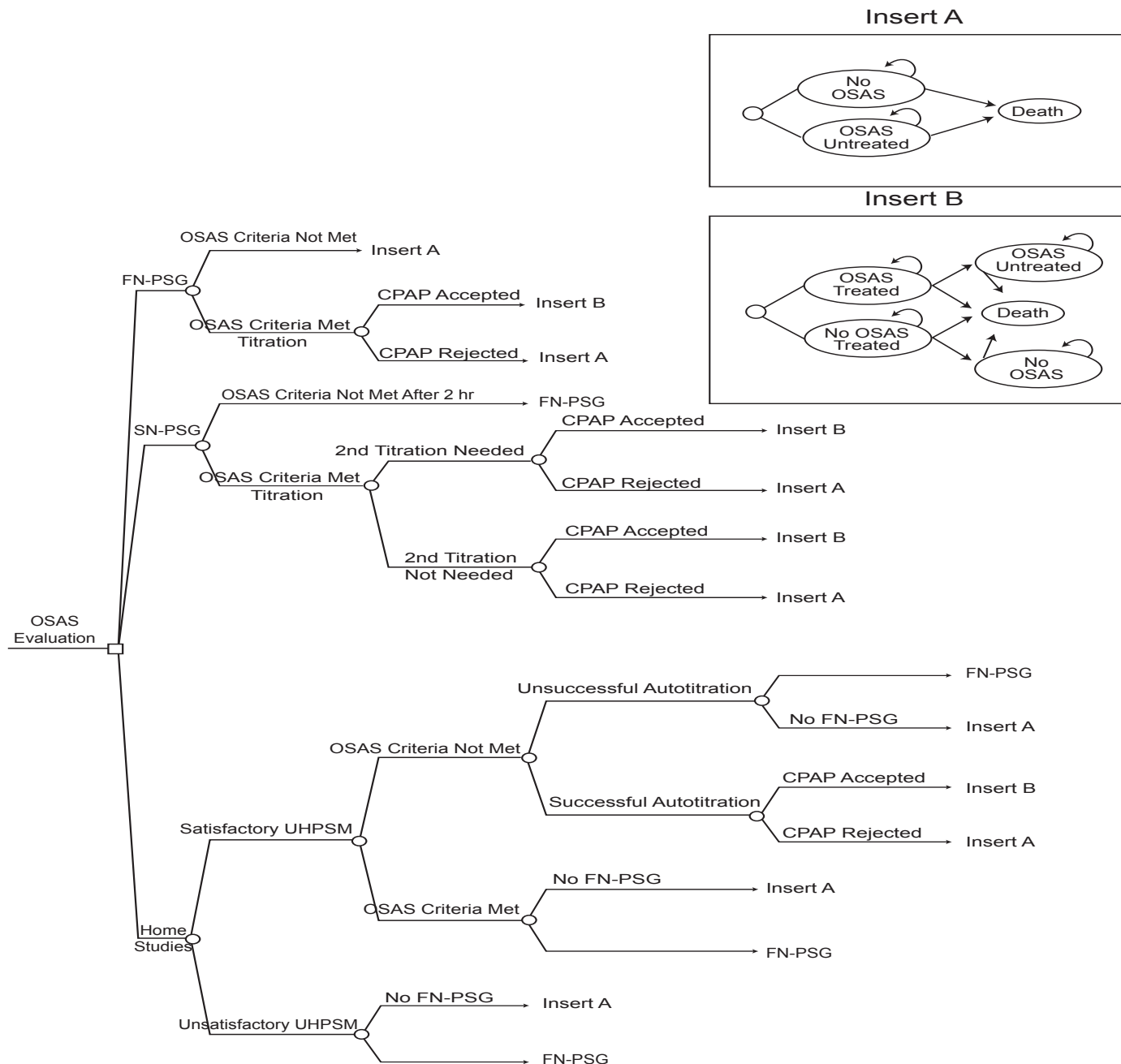


Figure 1—Decision tree for obstructive sleep apnea syndrome evaluation. Patients enter the tree through the decision node, which leads to the 3 pathways: (1) full-night polysomnography (FN-PSG); (2) split-night polysomnography (SN-PSG); and (3) home studies. Along each pathway, branching at the chance nodes represents the probability of obstructive sleep apnea syndrome (OSAS) diagnostic criteria being met, further testing, or patient acceptance of continuous positive airway pressure (CPAP) during or immediately after titration. Patients exit the diagnostic evaluation in 1 of 4 health states: (1) OSAS treated, (2) OSAS untreated, (3) no OSAS, or (4) no OSAS treated (false-positive diagnosis and accepted CPAP). The subsequent 5-year period is represented by a Markov cycle in which patients may die or remain in the health state. Patients who start off in the OSAS-treated or no-OSAS-treated states pass into the OSAS-untreated or no-OSAS health states if they discontinue CPAP use.

The FN-PSG pathway consists of overnight in-laboratory PSG followed by CPAP titration during a subsequent night, if OSAS criteria are met. Patients who fulfill the criteria either accept or reject CPAP treatment. Assuming that FN-PSG has a specificity of 1.0, the Markov cycles contain only the OSAS-treated and OSAS-untreated health states after CPAP titration.

On the SN-PSG pathway, patients are monitored during overnight PSG for at least 2 hours to identify those who meet OSAS criteria and are eligible for CPAP titration during the remainder of the overnight stay. If the OSAS criteria are not met, monitoring continues for the rest of the night, ie, the pathway is converted to FN-PSG. Patients who meet OSAS criteria after the first 2 hours and do not achieve adequate CPAP titration during the remainder of the night return to the laboratory on a subsequent night for CPAP titration.

The home studies pathway consists of unattended home partial sleep monitoring (UHPSM) followed by a night of CPAP autotitration, if OSAS criteria are met. Some of the UHPSM procedures will be unsatisfactory due to equipment or human error or both. If UHPSM is satisfactory and diagnostic criteria for OSAS are met, unattended home CPAP autotitration is performed during a subsequent night to determine the optimal fixed CPAP level. In cases in which UHPSM is unsatisfactory or negative or CPAP autotitration is unsuccessful, the patient is managed by the FN-PSG pathway. Not all of these patients report for further testing by overnight PSG. This analysis assumes that the patients who drop out remain undiagnosed and untreated.

Costs

The cost analysis was performed from the perspective of third-party payers, and only direct healthcare costs were considered. Although patients with untreated OSAS utilize more healthcare services than does the general population,^{3,4} the indirect costs have not been measured in the United States and the effect of CPAP treatment is unknown.

The costs of diagnosis and treatment were computed in 2004 US dollars using a global cost formula:

$$\text{Total_Cost} = \text{cOSA_Diagnosis} + \text{cTitration} + \text{cCPAP} + \text{cOffice_visits}$$

Because published methodology for standardized calculation of OSAS diagnostic and treatment costs is currently lacking, we used 2004 Medicare reimbursement rates as cost estimates for the base case (Table 1) and simulated within the model a wide range of payment rates used throughout the United States (50%-150% of the Medicare rate). Reimbursements were discounted at a rate of 3.0% annually.³⁷

Costs for all 3 pathways were adjusted with the assumption that 3.57% of PSG CPAP titrations would be repeated due to suboptimal initial procedures.^{14,29} Costs for long-term CPAP use were estimated according to previous reports of long-term CPAP compliance, assuming CPAP usage to be 80% at 3 months, 74% at 1 year, and 71% at 5 years.^{31,34,38,39}

Patients who refused CPAP or did not meet OSAS criteria were allowed 1 postevaluation office visit. Those who accepted CPAP after in-laboratory titration were assumed to have 1 postevaluation office visit during the subsequent month and biannual office visits throughout the period they continued treatment. In accordance with published practice parameters,²¹ it was assumed that patients diagnosed by the home-studies pathway had postevaluation monthly office visits during the first 3 months, visits every 3 months during the subsequent 9 months, and biannual visits thereafter while receiving CPAP treatment. Patients who initially accepted CPAP but discontinued it later during the 5-year time horizon were allowed no further office visits.

Outcome Measures

Each diagnostic pathway culminated in a combination of 4 health states: (1) OSAS treated, (2) OSAS untreated, (3) no OSAS, and (4) no OSAS treated. Pathway outcomes were influenced by the sensitivities and specificities of the diagnostic tests. For example, patients who did not meet OSAS criteria by full-night PSG included those with no OSAS as well as a small proportion (2.5%) in whom OSAS was missed (OSAS untreated). Similarly, patients on the split-night PSG pathway who accepted CPAP after the initial monitoring period included those with OSAS (OSAS treated) as well as a small proportion (1.8%) who would not have met OSAS criteria had they been monitored the full night (no OSAS treated). Over the 5-year time horizon, patients shifted from the OSAS-treated to the OSAS-untreated and from the no-OSAS-treated to the no-OSAS health states based on previously reported rates of long-term CPAP compliance.^{31,34,38,39}

Utilities for treated and untreated OSAS were determined by the standard gamble technique (Table 1). Consistent with our cohort, these utilities were derived from 2 series consisting mostly of individuals with moderate to severe OSAS.^{6,7} Although there was a systematic difference in the utility values reported from

the 2 studies, the difference between OSAS treated and OSAS untreated was the same (0.24). Results of the cost-effectiveness analysis did not differ when we ran the model using one set of utilities versus the other. We chose the utilities determined by Chakravorty⁷ because they were derived from a larger sample size in a prospective manner. We did not consider utilities determined by the EuroQol-5D⁴⁰ because this instrument does not address aspects of life affected by OSAS, like daytime sleepiness, calling into question its appropriateness in assessing health outcomes of individuals with sleep disorders.

Patients with no OSAS were assigned a utility value midway between the utilities for treated and untreated OSAS, according to the estimate of Chervin.²⁸ Like Chervin, we estimated a utility equivalent to untreated OSAS for the small number of treated patients with no OSAS, based on the reasoning that few would benefit and all would be subject to the discomfort of CPAP.²⁸ Each utility was discounted at a rate of 3.0% annually.³⁷

Health outcomes were expressed as quality-adjusted life years (QALYs), the product of the utility and life expectancy for the health state. Symptomatic persons found not to have OSAS by PSG and those with treated OSAS have been shown to have death rates similar to individuals without apparent sleep-disordered breathing.⁴⁰ We estimated life expectancies for patients in the OSAS treated, no OSAS, and no OSAS treated groups over the 5-year time horizon according to age- and sex-specific death rates of the general United States population.⁴¹ Death rates of patients with untreated OSAS were adjusted according to the higher risk (odds ratio 2.87, 95% confidence interval 1.17-7.51).⁴¹ Deaths were incorporated into the decision tree using Markov cycles.

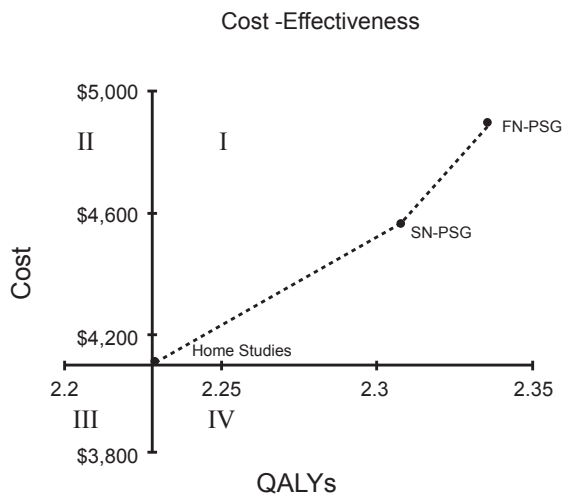
Base-Case Calculations

Rather than defining base-case parameters with point estimates without consideration of their uncertainties, a probabilistic approach was undertaken.⁴³⁻⁴⁵ Distributions appropriate to each parameter were defined using the point estimate as a measure of central tendency and estimating uncertainty from available published data. Beta distributions were used to model probability distributions of variables that take values from 0 to 1, such as probabilities and utilities. Costs were modeled using gamma distributions.

A Monte Carlo simulation with 10,000 iterations with simultaneous sampling from all parameter probability distributions was performed to determine incremental cost-effectiveness ratios. Mean values for expected costs, QALYs, and cost-effectiveness ratios over the 5-year horizon for each diagnostic pathway were calculated. The cost-effectiveness ratios were plotted on a cost-effectiveness plane (Figure 2). A diagnostic strategy was considered dominant over another if the total costs were lower and QALYs were the same or higher. Strategies that were more costly and more effective, in terms of QALYs, were assessed according to the incremental cost-effectiveness ratio (cost per QALY gained).

Univariate Sensitivity Analyses

One-way sensitivity analyses were performed over the range of published probabilities and test characteristics and reimbursement rates within the United States. In some cases, in which changes in 2 or more variables were closely related, the sensitivity analyses were correlated (performed simultaneously).



| Pathway | Expected Cost | QALYs | Cost-Effectiveness Ratio | Incremental Cost-Effectiveness Ratio |
|--------------|---------------|-------|--------------------------|--------------------------------------|
| FN-PSG | \$4,886 | 2.33 | \$2,092/QALY | \$11,586/QALY Gained |
| SN-PSG | \$4,565 | 2.31 | \$1,979/QALY | \$5,932/QALY Gained |
| Home Studies | \$4,096 | 2.23 | \$1,838/QALY | ----- |

Figure 2—Cost-effectiveness of the diagnostic pathways for the base case. Cost-effectiveness results for all 3 pathways lie in the first quadrant of the cost-effectiveness plane, indicating both increased cost and effectiveness for split-night polysomnography (SN-PSG) relative to the home studies pathway, and for full-night PSG (FN-PSG) relative to the split-night PSG and home-studies pathways. The slope of the line between any 2 points represents the incremental cost-effectiveness ratio for the 2 pathways. QALYs refers to quality-adjusted life years. Home studies refer to unattended home partial sleep monitoring followed by unattended continuous positive airway pressure autotitration on a subsequent night if obstructive sleep apnea syndrome is documented.

Probabilistic Sensitivity Analyses

The results of all iterations of the Monte Carlo simulation were plotted in the cost-effectiveness plane with incremental cost-effectiveness ratios for split-night PSG and full-night PSG versus home studies and full-night PSG versus split-night PSG in separate graphs. These data were evaluated in terms of the probability that a diagnostic pathway would meet the maximum amount a third-party payer is willing to pay (willingness-to-pay threshold). Cost-effectiveness ratios were transformed to net benefits,^{43,45} and acceptability curves were generated to assess the proportion of times each diagnostic strategy was cost-effective relative to the other strategies for a given willingness-to-pay threshold.

RESULTS

Base Case

Figure 2 presents the base-case cost-effectiveness ratio for each diagnostic pathway on the cost-effectiveness plane. None of the strategies is dominated by another. Both costs and QALYs are greatest for full-night PSG and lowest for home studies. Compared with home studies, the incremental cost-effectiveness ratio is \$5,932 per QALY gained for split-night PSG and \$7,383 for full-night PSG. The incremental cost-effectiveness ratio for full-night PSG compared with split-night PSG is \$11,586 per QALY gained. These values compare favorably with cost-effectiveness estimates for a variety of widely accepted interventions.⁴⁶

Univariate Sensitivity Analyses

Our model was robust to 1-way sensitivity analyses, except that the split-night PSG pathway dominated full-night PSG when both had the same rate of CPAP acceptance.

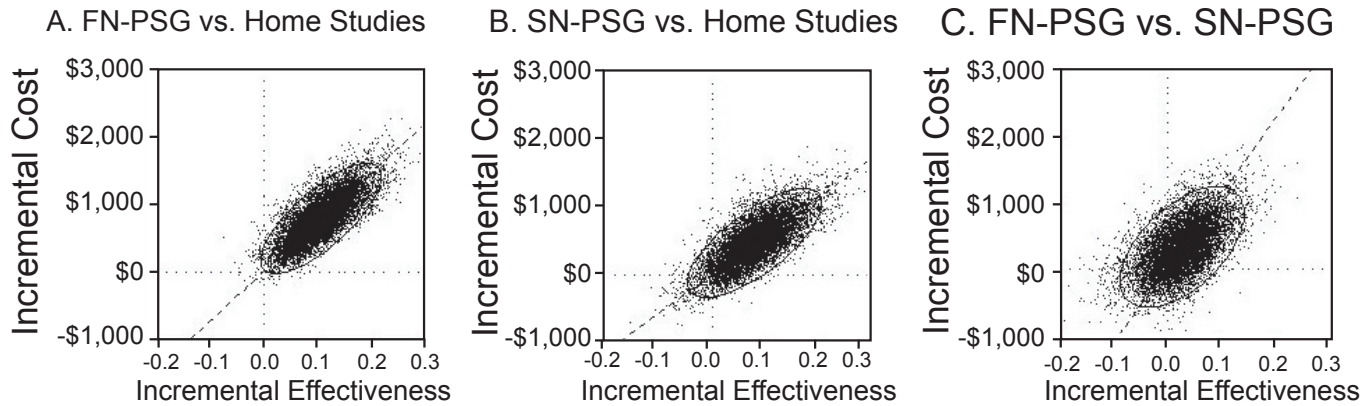
Probabilistic Sensitivity Analyses

Figure 3 displays scatterplots of the incremental cost-effectiveness ratios for all of the 10,000 Monte Carlo iterations. For full-night PSG versus home studies (Figure 3A), the ellipse defining the 95% confidence limit is almost completely contained within the first quadrant, indicating higher costs and higher QALYs for the full-night PSG pathway compared with home studies. Slight extensions into the second and fourth quadrants represent rare iterations in which full-night PSG was more costly and more effective or less costly and more effective than the home-studies pathway. In comparing split-night PSG and home studies (Figure 3B), the ellipse of the 95% confidence limit falls within all 4 quadrants, although 90% of the values lie within the first quadrant. When full-night PSG is compared with split-night PSG (Figure 3C), the incremental cost-effectiveness ratios are more widely distributed among the 4 quadrants. The slopes of the lines intersecting the origin on each of the cost-effectiveness planes represent willingness-to-pay thresholds for which the comparator pathway is cost-effective in exactly 50% of the iterations: \$5,827 for split-night PSG versus home studies, \$7,317 for full-night PSG versus home studies, and \$11,075 for full-night PSG versus split-night PSG.

Figure 4 shows pairwise cost-effectiveness acceptability curves for full-night PSG versus home studies, split-night PSG versus home studies, and full-night PSG versus split-night PSG across a range of willingness-to-pay thresholds. These acceptability curves represent the proportions of iterations in the Monte Carlo simulation that are cost-effective (in comparison with another pathway) as a function of a third-party payer’s willingness to pay for additional QALYs. For example, if a payer is willing to spend \$10,000, full-night PSG and split-night PSG represent cost-effective alternatives to home studies in more than 80% of simulation iterations. Above a willingness-to-pay threshold of \$20,000, both full-night PSG and split-night PSG are more cost-effective than home studies in more than 90% of iterations. Fewer than half of iterations result in full-night PSG being a cost-effective alternative to split-night PSG when willingness to pay is \$10,000 and only two-thirds when willingness to pay is \$30,000.

The y intercepts of the curves in Figure 4 represent the 1-sided p value for the difference in costs of the 2 pathways. The p value for the difference in effectiveness is 1 minus the upper (asymptotic) limit of the curve.⁴⁵ In the comparison of the full-night PSG and home-studies pathways, the p value for the difference in costs was 0.004, whereas, for the difference in effectiveness, the p value was 0.013.

Figure 5 shows acceptability curves for the 3 pathways when the cost-effectiveness ratios are transformed to net benefits. The net-benefit acceptability curves demonstrate the proportion of evaluations that are cost-effective for each pathway over a range of willingness-to-pay thresholds.^{43,45} At each willingness-to-pay threshold, the curves sum to 1.0, allowing identification of the pathway that is most frequently cost-effective. Home studies is the pathway most frequently cost-effective when willingness to pay is less than \$6,500, as is split-night PSG when willingness to pay is between \$6,500 and \$11,500, and full-night PSG, when



D. Proportion of Simulation Results in Each Quadrant

| | Quadrant | | | |
|-------------------|----------|------|------|------|
| | I | II | III | IV |
| FN-PSG vs. HS | 0.99 | 0.01 | 0.00 | 0.00 |
| SN-PSG vs. HS | 0.90 | 0.03 | 0.03 | 0.04 |
| FN-PSG vs. SN-PSG | 0.65 | 0.16 | 0.10 | 0.08 |

Figure 3—Incremental cost-effectiveness for the 10,000 Monte Carlo simulations on the cost-effectiveness plane. The scatterplots show the distribution of incremental cost-effectiveness ratios for full-night polysomnography (FN-PSG) versus home studies (HS) (A), SN-PSG versus Home Studies (B), and FN-PSG versus SN-PSG (C) for all 10,000 iterations of the Monte Carlo simulation. The ellipses show the central 95th percentile of each distribution. The overlaid lines have slopes equal to the willingness-to-pay threshold that would render 50% of the evaluations acceptable to a third-party payer.

The proportions of simulation results found in each quadrant of each pairwise scatterplot are shown in the table. The quadrants begin in the upper right (Quadrant I) and go counterclockwise, with Quadrant IV in the lower right.

willingness to pay is greater than \$11,500.

DISCUSSION

The growing appreciation of OSAS as a high-prevalence disorder has placed new demands on healthcare resources. In response, newer diagnostic tests have come into use with the intent of lowering costs and improving access. The assessment and treatment of OSAS is a complex process involving a series of diagnostic and treatment options. In evaluating the cost-cutting potential of newer tests and strategies, the entire process must be considered. Our model compares the cost-effectiveness of 3 widely used approaches to OSAS diagnosis and CPAP titration: (1) full-night PSG, (2) split-night PSG, and (3) UHPSM with CPAP autotitration (home studies). Two of these strategies, split-night PSG and home studies employ less-costly diagnostic procedures than does full-night PSG but require some patients to undergo additional procedures to achieve the same health benefit.

Our study sought to simulate conditions that exist in current medical practice. Published CPAP acceptance rates have been higher with full-night PSG³¹⁻³⁴ than with split-night PSG²⁵⁻²⁷ and home studies,²⁰ possibly due to greater opportunity for patient education and CPAP acclimatization. Reports have also noted that not all patients follow up in the sleep laboratory after UHPSM is nondiagnostic^{16,20,24} or CPAP autotitration is unsuccessful,²³ possibly due to frustration or the perception that additional testing is not needed or because the patient “fell between the cracks” during

the more-arduous evaluation. Our model took into consideration variable CPAP acceptance and dropouts.

Our base-case analysis identified tradeoffs of overall costs versus effectiveness among the 3 pathways. Both costs and QALYs were lowest for the home-studies pathway. Dropouts and lower rates of CPAP acceptance in the home-studies pathway led to a greater number of patients with untreated OSAS. The home-studies pathway utilized the least-expensive diagnostic tests, but substantial savings resulted primarily because fewer patients received long-term CPAP treatment, which, over 5 years, cost 10 times more than the initial home-study evaluation.

When plotted on a cost-effectiveness plane, the cost-effectiveness ratios of all 3 strategies lie in the first quadrant, indicating increasing cost and effectiveness as split-night PSG is substituted for home studies and as full-night PSG is substituted for split-night PSG. The point at which the benefits of more widespread OSAS diagnosis and CPAP treatment justify the greater expense is a value judgment based on willingness to pay.^{45,46} The costs for additional QALYs incurred by full-night PSG and split-night PSG over home studies, and even by full-night PSG over split-night PSG, compare favorably with cost-utility estimates for a variety of widely accepted healthcare interventions.⁴⁶

Probabilistic sensitivity analysis takes into consideration the uncertainty of each parameter in the model and allows parameters to vary simultaneously, providing an appreciation for the range of possible results. In comparing the full-night PSG and home-stud-

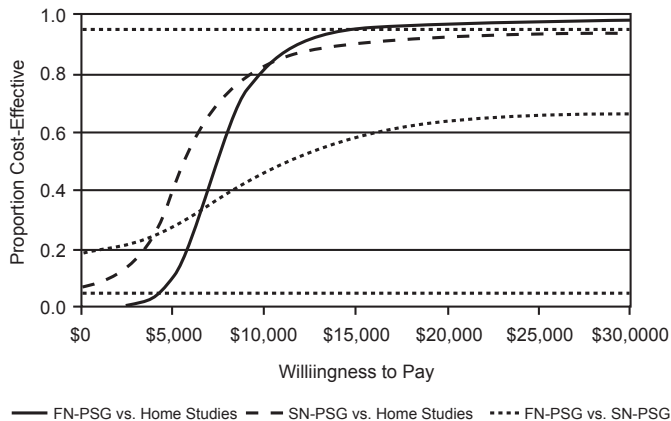


Figure 4—Pairwise acceptability curves. Acceptability curves derived from the scatterplots represent the proportion of trials that would be acceptable according to a third-party payer’s willingness to pay to attain additional quality-adjusted life years. The horizontal broken lines indicate 5% and 95% probability. The y intercept represents the 1-sided p value for the difference in cost. The p value for the difference in effectiveness is the upper limit of the curve subtracted from 1.⁴⁵ FN-PSG refers to full-night polysomnography; SN-PSG, split-night polysomnography.

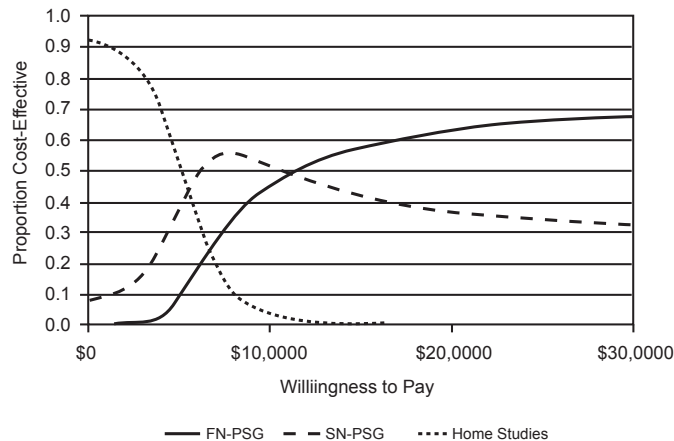


Figure 5—Net benefits acceptability curves. Each curve represents the proportion of evaluations that were cost-effective relative to the other pathways across a range of willingness-to-pay thresholds. FN-PSG refers to full-night polysomnography; SN-PSG, split-night polysomnography.

ies pathways, a significant difference in cost and effectiveness is apparent, and it is reasonable to assume that full-night PSG is almost always more costly and more effective than home studies. This assumption seems less certain when comparing split-night PSG and home studies or full-night PSG and split-night PSG.

These findings can be put into perspective when viewed in relation to a third-party payer’s willingness to pay to provide greater health benefits for its beneficiaries. Our study indicates that at the lowest levels of willingness to pay, the home-studies pathway must be chosen by default, but, as willingness to pay increases, there is a steep increase in the proportion of split-night PSG or full-night PSG evaluations that fall within the budget.

Our results do not indicate a significant difference in cost or effectiveness when comparing the full-night PSG and split-night PSG alternatives. Although full-night PSG may often be more costly and more effective than split-night PSG, our analysis does not identify a specific point of willingness to pay at which full-night PSG is substantially more cost-effective than split-night PSG. Considerations other than cost-effectiveness, such as the availability of beds in the sleep laboratory and convenience, may be important in choosing between these 2 options.

When cost-effectiveness ratios are transformed to net benefits, the 3 diagnostic strategies can be compared with one another. The net-benefits acceptability curves displayed in Figure 5 reinforce the concept that, when willingness to pay is restricted to low amounts, the home-studies pathway is most often cost-effective, but for higher willingness to pay, split-night PSG or full-night PSG is usually more cost-effective.

Only a few published cost-effectiveness studies have compared different strategies for OSAS diagnosis. Differences in methodology, study design, and assumptions limit detailed comparisons with these analyses. For example, Reuveni and colleagues²⁹ found lower overall process costs for attended compared with unattended studies but used a 2-level decision tree, used microcosting rather than reimbursement rates, and did not consider incremental cost-effectiveness ratios. Chervin and colleagues²⁸ constructed a decision-tree model that compared the cost-utility of unattended home

testing and empiric treatment with full-night PSG in the diagnosis of OSAS but did not include split-night PSG in their study. They concluded that evaluation of OSAS by full-night PSG is more costly and more effective than a home-study approach and that the cost per QALY gained for full-night PSG is reasonable.

Our study targeted a cohort of symptomatic individuals at moderate to high risk for OSAS, which did not include children or elderly persons. The results of our analysis may not apply to asymptomatic patients or groups at lower risk and should not be considered valid for pediatric or geriatric populations. Further studies modeled to assess the cost-effectiveness of diagnostic strategies for these groups would be of interest.

Our model offers a roadmap for where interventions and technology might lower costs or improve the effectiveness of split-night PSG or home studies relative to the conventional full-night PSG approach. For example, our 1-way sensitivity analysis suggests that, if the rates of CPAP acceptance after split-night PSG and full-night PSG are equal, split-night PSG dominates the full-night PSG strategy. Patient education and carefully constructed titration protocols might improve CPAP acceptance for both the split-night PSG and home-studies pathways. Advances in technology that simplify and improve sensitivity and specificity of unattended sleep monitoring might enhance the efficiency of the home-studies approach. Whether value could be achieved by the additional expenditures for such interventions or technical improvements would require further investigation.

Our study has some limitations. Because widely applicable cost data for OSAS diagnostic and CPAP titration procedures and long-term CPAP treatment are lacking, we used Medicare reimbursement rates as proxies, assuming that any variation among these tests would be constant and affect each of the pathways in a similar manner. To address this limitation, our model included simulations with a wide range of reimbursement rates used by sleep programs throughout the United States. There was, however, potential for an underestimation of costs for the home-studies pathway because Medicare rates for unattended home studies may not hold across the range of technologies currently available or cover nonoperational costs like lost or damaged equipment.

Our cost estimates did not include indirect costs such as health-care and non-healthcare costs arising from complications of un-

treated OSAS. Although data allowing estimation of these indirect costs that would apply to this study are not available, previous reports indicate that they are considerable.^{3,4} Furthermore, our study took the narrower perspective of third-party payers rather than of society. A more comprehensive analysis considering indirect costs and societal issues could yield different conclusions.

Some potentially useful options for the evaluation and treatment of OSAS were not addressed in this analysis. For example, the combination of full-night PSG followed by home CPAP autotitration for patients found to have OSAS has been suggested as a potentially cost-effective approach.²²⁻²⁴

Another limitation was that our model required patients to remain in the no-OSAS and OSAS-untreated health states throughout the 5-year time horizon. Some patients who did not meet OSAS criteria might have benefited from CPAP treatment, and others might have been well served by an evaluation for an alternative condition. Some patients with OSAS who initially rejected CPAP might have reconsidered later. Treatment alternatives to CPAP, such as oral appliances or surgical procedures, were not included in our model.

In summary, we found that all 3 of the diagnostic pathways were comparable with widely accepted healthcare interventions, in terms of cost-effectiveness. As split-night PSG is substituted for home studies and as full-night PSG is substituted for split-night PSG, both costs and health benefit increase—more patients are accurately diagnosed and more with OSAS are successfully treated. These findings suggest that the current increasing demand for OSAS assessment and treatment may be dealt with differently across the span of individual healthcare systems and providers. For some, the options may be limited; constraints in funding, space, and trained personnel require that the escalating need be accommodated in the home. For those who are in the position of choosing between options of increasing capacity for in-laboratory testing versus initiating or expanding programs that rely on unattended studies, our study points out the complexities that should be considered.

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