pii: jc-17-00466 http://dx.doi.org/10.5664/jcsm.7060

JCSM
Journal of Clinical Sleep Medicine

SCIENTIFIC INVESTIGATIONS

Analyses of the Complexity of Patients Undergoing Attended Polysomnography in the Era of Home Sleep Apnea Tests

Brendon Colaco, MBBS[1,2]; Daniel Herold, RPSGT[1]; Matthew Johnson, MPH[3]; Daniel Roellinger[3]; James M. Naessens, ScD[3,4]; Timothy I. Morgenthaler, MD, FAASM[1,2]

[1]Mayo Clinic Center for Sleep Medicine, Mayo Clinic, Rochester, Minnesota; [2]Division of Pulmonary and Critical Care Medicine, Mayo Clinic, Rochester, Minnesota; [3]Robert D. and Patricia E. Kern Center for the Science of Healthcare Delivery, Mayo Clinic, Rochester, Minnesota; [4]Division of Health Care Policy & Research, Mayo Clinic, Rochester, Minnesota

Study Objectives: Health care complexity includes dimensions of patient comorbidity and the level of services needed to meet patient demands. Home sleep apnea tests (HSAT) are increasingly used to test medically uncomplicated patients suspected of having moderate to severe obstructive sleep apnea (OSA). Patients with significant comorbidities or other sleep disorders are not candidates for HSAT and require attended in-center polysomnography. We hypothesized that this trend would result in increasingly complex patients being studied in sleep centers.

Methods: Our study had two parts. To ascertain trends in sleep patient comorbidity, we used administrative diagnostic codes from patients undergoing polysomnography at the Mayo Clinic Center for Sleep Medicine from 2005 to June 2015 to calculate the Charlson and the Elixhauser comorbidity indices. We measured the level of services provided in two ways: (1) in a subset of patients from the past 2 months of 2015, we evaluated correlation of these morbidity indices with an internally developed Polysomnogram Clinical Index (PSGCI) rating anticipated patient care needs from 0 to 3 and (2) we measured the sleep study complexity based on polysomnography protocol design.

Results: In 43,780 patients studied from 2005 to June 2015, the Charlson index increased from a mean of 1.38 to 1.88 (3.1% per year, $P < .001$) and the mean Elixhauser index increased from 2.61 to 3.35 (2.5% per year, $P < .001$). Both comorbidity indices were significantly higher at the highest (Level 3) level of the PSGCI ($P < .001$), and sleep study complexity increased over time.

Conclusions: The complexity of patients undergoing attended polysomnography has increased by 28% to 36% over the past decade as measured by validated comorbidity indices, and these indices correlate with the complexity of rendered care during polysomnography. These findings have implications for increasing requirements for staffing, monitoring capabilities, and facility design of future sleep centers.

Commentary: A commentary on this article appears in this issue on page 499.

Keywords: complexity, health services, home sleep apnea tests, morbidity, polysomnography, sleep medicine, technologist

Citation: Colaco B, Herold D, Johnson M, Roellinger D, Naessens JM, Morgenthaler TI. Analyses of the complexity of patients undergoing attended polysomnography in the era of home sleep apnea tests. *J Clin Sleep Med.* 2018;14(4):631–639.

BRIEF SUMMARY

Current Knowledge/Study Rationale: There have been no prior studies specifically evaluating the complexity of patients undergoing polysomnography over time. However, several factors may be increasing complexity of such patients: (1) home sleep apnea tests draw less complex patients away from attended polysomnography, (2) greater percentages of patients seeking medical care have multiple chronic health conditions, and (3) advances in the type of respiratory support devices employed by sleep medicine specialists are capable of supporting more complex patient needs.

Study Impact: Our data demonstrate that the complexity of patients being studied increased by nearly 30% and that care requirements increase with complexity measures. This trend suggests the need for higher levels of training and special equipment, with potential resultant increased costs of attended polysomnography tests in the future.

INTRODUCTION

Current guidelines recommend that home sleep apnea tests (HSAT) may be used as an alternative to attended polysomnography to diagnose obstructive sleep apnea (OSA) in patients with a high pretest probability of moderate to severe OSA and without several significant comorbidities that would reduce the accuracy of HSAT.[1] HSAT followed by auto-adjusting positive airway pressure therapy appears to be a less costly management strategy for many such patients,[2] and accordingly there has been a 400-fold increase in utilization for HSAT in the recent past.[3] If patients without significant comorbidities are increasingly being diagnosed with HSAT, it follows that patients with comorbidities and those with central sleep apnea, hypoventilation syndromes, and developmental or neurologic disorders might preferentially be aggregated into sleep centers where attended polysomnography is performed.

Most sleep centers are best equipped to provide care for medically uncomplicated ambulatory patients. Staffing and testing models listed in accreditation standards for sleep centers have not changed significantly in the past decades. The staffing and technical specifications for sleep laboratories were updated in 2016 by the American Academy of Sleep Medicine (AASM).[4] The document recommends a 2:1 patient technologist ratio,

Downloaded from jcsm.aasm.org by 129.176.151.19 on December 10, 2020. For personal use only. No other uses without permission. Copyright 2020 American Academy of Sleep Medicine. All rights reserved.

but also stipulates that technologist staffing must be adequate to address the workload of the facility and ensure the safety of patients. As the medical complexity of patients served by a sleep center increases, there may be increased requirements for respiratory and nursing needs. For example, most sleep centers are not equipped with safe patient handling equipment particularly needed in bariatric patients or those with impaired mobility.[5,6] Managing fall risks may require increased staffing levels.[7] Patients with cognitive or behavioral problems may require skill sets for care not often included in respiratory therapy or sleep technologist training. Given these concerns, it would be important to determine if there are trends toward increased patient morbidity served in sleep centers, and even more, to determine if there was a way to anticipate needs in order to enhance patient safety and quality of care.

Although it is widely accepted that patients interacting with the health care system have become more complex over time, there is no widely accepted definition of complexity.[8–10] Most recent efforts to characterize patient complexity acknowledge several axes of importance, including coexistence of multiple medical illnesses, mental illnesses, substance addiction, socioeconomic challenges, and/or behaviors or traits that complicate care for chronic medical illnesses, and even prior costs of care.[10,11] We approached the measurement of health care complexity in two ways. First, we used indexes of comorbidity to represent the disease burdens of patients being tested. Second, we developed measures to represent the complexity of services rendered during testing.

Comorbidity may be defined as the total burden of illness unrelated to the principal diagnosis. Typically, comorbidity scores have been used to adjust for confounding conditions that affect the outcome variable of interest. The Charlson comorbidity index was developed on a cohort of cancer patients by identifying numerous clinical conditions through review of hospital charts and assessing their value to predict mortality in 1 year.[12,13] It is a weighted index, constructed from over 19 comorbid conditions. Comorbidities are weighted from 1 to 6 for mortality risk and disease severity, and then summed to form the total score, an estimator of disease burden. Extracting from administrative data, it combines comorbidities into a single numeric score stratifying patients into subgroups based on disease severity. The index has been validated in large databases and can be used with International Classification of Diseases (ICD)-9-CM and ICD-10 codes. The index is both reliable and valid and has been widely used in prior research, including in development of models to predict costs for chronic illness as a measure of health care utilization among primary care patients.[14]

Elixhauser et al. developed a comorbidity index composed of a comprehensive set of 30 comorbidities defined using ICD-9-CM diagnosis codes from administrative data on a cohort of national hospital inpatients.[15] The index can be calculated using both ICD-9-CM and ICD-10 codes. The index correlates with length of stay, hospital charges, and mortality both for heterogeneous and homogenous disease groups with disparate principal diagnoses.[16–18] The Elixhauser index uses both diagnosis-related groups and secondary ICD-9-CM diagnostic codes from inpatient claims to identify 30 unweighted comorbidity indicators to produce a comorbidity count. Our adaptation of the Elixhauser index also incorporates diagnostic codes from prior ambulatory care episodes.

We chose to use both Charlson comorbidity index and the Elixhauser index as these two indices adequately capture comorbidity profile for both outpatient and inpatient settings and could provide complementary information. Although the Charlson index was developed to focus on chronic comorbid conditions related to mortality and has more applicability to the ambulatory or outpatient setting, the Elixhauser index was constructed using hospital inpatients focused on the effect of both chronic and acute comorbidities on resource use and inpatient outcomes. By choosing these two indices we thought we were adequately capturing the medical complexity of patients based on data abstracted from our administrative databases.

One definition of the complex patient was offered by Weiss, as "one for whom clinical decision-making and required care processes are not routine or standard."[19] Neither of the aforementioned indices incorporates a measure of the care services directly associated with the specific episode of care. Therefore, we developed two measures directly reflecting the intensity of services required to provide the comprehensive attended polysomnography. The first was designed from the perspective of the sleep technologists providing services during polysomnography, which we call the Polysomnogram Clinical Index (PSGCI), and which will be described in the next paragraphs (**Figure 1**). We also generated a sleep study complexity measure for individual sleep studies using a Likert scale based on the study protocol and type of positive airway pressure employed during the study (see Methods, **Table 1**).

Our study examined whether there has been a change in the medical complexity or sleep test complexity of patients studied in a tertiary sleep laboratory over the past 10 years. Further, we evaluated how well our PSGCI correlated with the sleep complexity measure or Charlson and Elixhauser comorbidity indices. We also examined if complexity as measured from the Likert scale based on study protocol and type of positive airway pressure (PAP) therapy titration increased over time and if this measure correlated with our PSGCI. We hypothesized that the comorbidity indices have increased over time, and that the complexity of care during a polysomnography would correlate with the degree of comorbidity in our sleep center patients.

METHODS

Data from the electronic medical records were extracted for all patients studied at the Mayo Clinic Center for Sleep Medicine's sleep laboratory in Rochester, Minnesota from January 2005 through June 2015. Patients were identified using administrative claims data, capturing all adult (age 18 years or older) patients with polysomnography (CPT codes 95810 and 95811). Each polysomnogram was treated as a discreet record. Multinight studies were counted for each night.

At the Mayo Clinic Center for Sleep Medicine all patients undergoing polysomnography are first seen in consultation by sleep specialists, who subsequently provide customized orders for sleep testing. Included in the orders are requests for specific

Downloaded from jcsm.aasm.org by 129.176.151.19 on December 10, 2020. For personal use only. No other uses without permission.
Copyright 2020 American Academy of Sleep Medicine. All rights reserved.

Figure 1—Schema of the Polysomnogram Clinical Index.

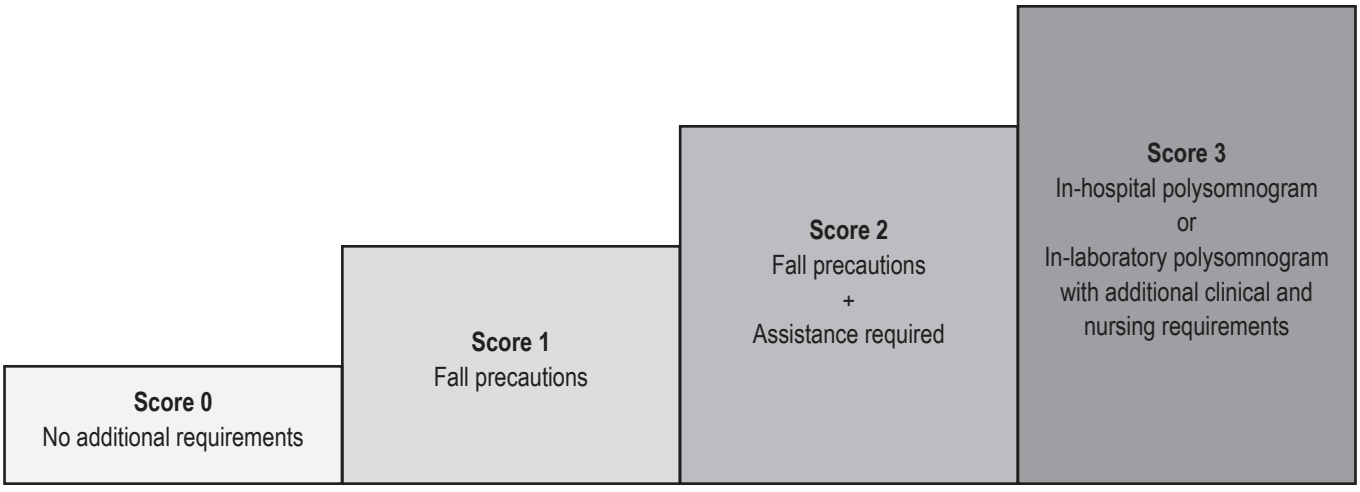


Table 1—Assessment of sleep study complexity based on type of study protocol and type of PAP therapy used.

Likert Scale Value	Type of Study/PAP
1	Diagnostic polysomnogram
2	Polysomnogram with parasomnia protocol (requiring special precautions and monitoring)
3	Polysomnogram with oxygen therapy titration
4	Polysomnogram with CPAP and or BPAP-S titration
5	Polysomnogram with CPAP and or BPAP-S with oxygen therapy titration
6	Polysomnogram with advanced PAP therapy (ASV, Auto SV, BPAP-ST, IVAPS, AVAPS) titration
7	Polysomnogram with advanced PAP (other than CPAP or BPAP-S) and oxygen therapy titration, Study with parasomnia protocol with PAP therapy with or without oxygen therapy titration
8	Portable polysomnogram (hospital study)

ASV/Auto SV = adaptive servoventilation, AVAPS = average volume-assured pressure support, BPAP-S = bilevel positive airway pressure in spontaneous mode, BPAP-ST = bilevel positive airway pressure with back up respiratory rate, CPAP = continuous positive airway pressure, IVAPS = intelligent volume-assured pressure support, PAP = positive airway pressure.

diagnostic monitoring and therapeutic interventions. To assist in operational planning for each night's staffing and equipment needs, we had previously developed the PSGCI (**Figure 1**). A score from zero to 3 is assigned based on the polysomnography orders generated by the sleep specialist, who is familiar with the patient's entire medical history. The default score is zero and indicates a routine patient with no additional requirements. A score of 1 is assigned when fall precautions are required. A score of 2 is assigned if fall precautions and additional assistance (eg, patient may require help with ambulation, reorientation, assistance with nebulizer therapy, etc.) may be required through the night. Finally, a score of 3 denotes an in-hospital study wherein the patient has need for clinical and nursing services through the night. This score was developed to assist the lead technologist to plan for staffing and equipment needs for each night's laboratory operations. Elements of the PSGCI were prospectively captured and calculated for October and November 2015.

Sleep laboratory data available between 2009 and 2016 were also analyzed to create a sleep study complexity measure. Based on these data each discreet study was assigned a Likert scale based value, which was determined based on the study protocol and the type of PAP deployed as displayed in **Table 1**. The sleep study complexity measure was assigned to individual studies based on our (BC, TIM) clinical judgement of what was perceived to be a more complex study. For example, a diagnostic polysomnogram was assigned a lower rating than a polysomnogram with a parasomnia protocol, which in turn was assigned a lower rating compared to a split-night study where continuous PAP and auto-adjusting PAP were both tried. When PAP therapy was used, the highest level of PAP therapy employed was considered to evaluate the study in terms of complexity.

To assess possible changes in the clinical complexity of patients over time, all diagnoses (ICD-9 code prior to October 2015 and ICD-10 codes after that date) billed within Mayo Clinic (both clinic and hospital) during the 3 years prior and 30 days following the sleep study were included. These diagnoses were used to calculate the Charlson comorbidity index and the Elixhauser comorbidity count.[12,15] The ICD-9 codes utilized included ischemic heart disease (ICD-9 codes 410.X–414.X), history of stroke or cerebrovascular disease (430.X, 431.X, 432.X,

Downloaded from jcsm.aasm.org by 129.176.151.19 on December 10, 2020. For personal use only. No other uses without permission.
Copyright 2020 American Academy of Sleep Medicine. All rights reserved.

434.X, 435.X, 436.X, and 437.1), valvular disease (424.0–424.3), heart failure (428.X), hypertension (401.X–405.X), chronic pulmonary disease (490.X–505.X, 506.4), history of depression (296.2X, 296.3X, 300.4, 309.1, and 311), diabetes (250.X), plegia (344.00–344.1), or movement disorders (333.0, 332.X). These scores would best capture any clinical complexities such as oxygen dependency or paraplegia or quadriplegia that would have been present on the night of the study.

In addition, we extracted each patient's body mass index (BMI) using the recorded weight closest to the sleep study within 6 weeks. Patient height values were accepted within 2 years; 92.0% of sleep studies had valid BMI measures.

Analysis of trends over time was based on monthly data. We performed a regression analysis of volume, demographics, BMI, and each mean complexity index for the entire time interval. Additional regression models of comorbidity indices over time adjusting for age, sex, BMI, and race were developed. Data are displayed in tables according to first and last year of analysis. However, statistical significance was based on a Student *t* test assessing for a non-zero slope of the regression line across the entire study period. Because the PSGCI is calculated as a score from 0 to 3, we performed an analysis of variance comparing the mean comorbidity indices and the sleep study complexity index for each level of PSGCI. All analyses were performed using SAS 9.4 (SAS Institute, Cary, North Carolina, United States). The conduct of this study was approved by the Mayo Clinic Institutional Review Board.

RESULTS

Our sample consisted of 43,780 patients who underwent polysomnography between January 2005 through June 2015 at the Center for Sleep Medicine Laboratory, Mayo Clinic, Rochester, Minnesota. **Table 2** summarizes the volume of sleep studies, mean morbidity scores, sleep complexity index, and demographic characteristics (age, sex, patient residence), overall and for each of the first and last year. A total of 90.9% of patients underwent a single sleep study, whereas 8.1% underwent two studies in the 10.5-year timeframe. One patient underwent six studies and four patients had five. The overall mean age of the patients undergoing attended polysomnography between January 2005 and June 2015 was 58.2 years with a monthly average ranging between 55.7 and 60.7 years. There was equal distribution of the sample among age groups older than 50 years. Of the overall sample, 39.8% were female. The overall mean BMI was 33.2 kg/m^2 with monthly average ranging between 32.1 and 35.2 kg/m^2. Over time the demographics showed that our patients became significantly older, more female, included more non-white patients, and increased allocation of "unknown" toward "white" patients. There was a significant, but small, decrease in mean BMI, with more underweight and fewer obese patients seen over time. Any change in geographic origin over time was also small with a higher proportion of local patients being seen recently.

Figure 2 provides plots of means with regression lines of the Charlson and Elixhauser comorbidity indices over the 10-year period. The Charlson index increased from a mean of 1.38 in 2005 to 1.88 in 2015 (3.1% per year); the mean Elixhauser count went from 2.61 to 3.35 (2.5% per year). The Charlson index increased 0.029 units per year ($P < .001$) and the Elixhauser increased 0.045 units per year ($P < .001$) based on regression analysis. These significant changes in morbidity annually were also present in the regression analyses adjusted for age, sex, BMI, and race. Meanwhile, volumes were essentially flat (3,943 to 3,774 studies in same timeframes). Sleep study complexity based on the Likert scale also increased at a small, but significant trend moving from a monthly mean of 3.89 in the first year to a monthly mean of 4.02 in the final year of our assessment.

Table 3 presents the percent of patients with specific comorbidities overall, in the first and last year, as well as the change per year based on the regression over time. Significant increases in prevalence over time occurred for peripheral vascular disease, moderate/severe renal disease, mild liver disease, dementia, prior myocardial infarct, and hemiplegia. Meanwhile, no significant increases were seen for the percent of patients with chronic obstructive lung disease, diabetes, cerebrovascular disease, or ulcers.

For the separate sample of 320 patients who underwent attended polysomnography during the months of October and November 2015, mean Charlson and Elixhauser comorbidity indices were compared across levels of the PSGCI. **Table 4** summarizes the volume of sleep studies and demographic data for this subset of the study sample. As seen in **Figure 3**, the mean Charlson comorbidity index was similar at PSGCI levels 0, 1, and 2, but substantially higher at level 3 ($P < .001$). Meanwhile, the Elixhauser comorbidity index was significantly higher for PSGCI level 3 than for levels 0 and 1 ($P < .001$).

DISCUSSION

We have shown that the complexity of patients undergoing polysomnography, as reflected by the Charlson and Elixhauser comorbidity indices, has increased approximately 30% over a 10-year period. We have also shown that there is a correlation between these indices and the care requirements during polysomnography as reflected by the PSGCI, suggesting this also has increased over the recent decade. Furthermore, the complexity of studies being performed as reflected by our sleep study complexity score (**Table 1**) also increased over this decade. These results all support our hypotheses that the complexity of patients being studied in sleep laboratories is increasing and suggest that, despite many improvements in the technology associated with polysomnography and positive airway pressure therapy, the care requirements for patients during testing are also increasing over time.

Ours is the first study to examine the complexity of patients seen in a sleep center using standardized comorbidity measures either cross-sectionally or over time. Prior related work had examined increasing obesity and its effect on the increased severity of OSA over time, but these studies had not examined other diagnoses as contributors to morbidity nor did the study populations include patients who were studied for

Downloaded from jcsm.aasm.org by 129.176.151.19 on December 10, 2020. For personal use only. No other uses without permission.
Copyright 2020 American Academy of Sleep Medicine. All rights reserved.

Table 2—Summary of sleep study volumes, comorbidity scores, and demographic data.

	All Years Combined	2005	2015	Change Per Year (Slope)	Trend Test Over Months (*P*)
Volumes (n)					
Total volume of sleep studies	43,780	3,943	3,774		
Total unique encounters	43,178	3,936	3,729		
Total unique patients	39,709	3,824	3,602		
Morbidity Indices					
Mean Charlson index	1.59	1.37	1.83	.029	< .001
Mean Elixhauser index	2.89	2.61	3.28	.045	< .001
Sleep Study Complexity					
Mean	3.96	3.89	4.02	.015	.003
Demographics					
Female (% of sleep studies)	40	40	41	.296	.001
Body Mass Index					
Mean (kg/m^2)	33.22	33.59	33.35	−.050	.002
Underweight (%)	9	5	7	.413	.001
Normal (%)	10	10	11	.115	.047
Overweight (%)	24	25	24	.074	.361
Obese Class I (%)	26	27	25	−.278	< .001
Obese Class II (%)	16	16	16	−.180	.004
Obese Class III (%)	15	17	17	−.143	.044
Age (% of sleep studies)					
< 50	26	28	25	−.357	< .001
50–60	26	25	25	.014	.865
61–70	24	24	25	.238	.002
> 70	24	23	25	.105	.300
Geographic Origin (% of sleep studies)					
Local	39	39	40	.420	.002
Regional	21	19	19	−.097	.419
National	37	40	38	−.497	< .001
International	2	1	3	.191	< .001
Unknown/other	< 1	< 1		−.016	< .001
Race Distribution (% of sleep studies)					
Black/African American	1	1	2		
American Indian/Alaskan native	< 1	< 1	< 1		
Asian	1	< 1	2		
Hispanic or Latino	< 1	< 1	0		
Pacific Islander	< 1	0	< 1		
White	87	78	90		
Not available	10	20	6		
Race Collapsed* (% of sleep studies)					
White	87	78	90	1.230	< .001
Non-white	3	2	4	.168	< .001
Unknown	10	20	6	−1.400	< .001

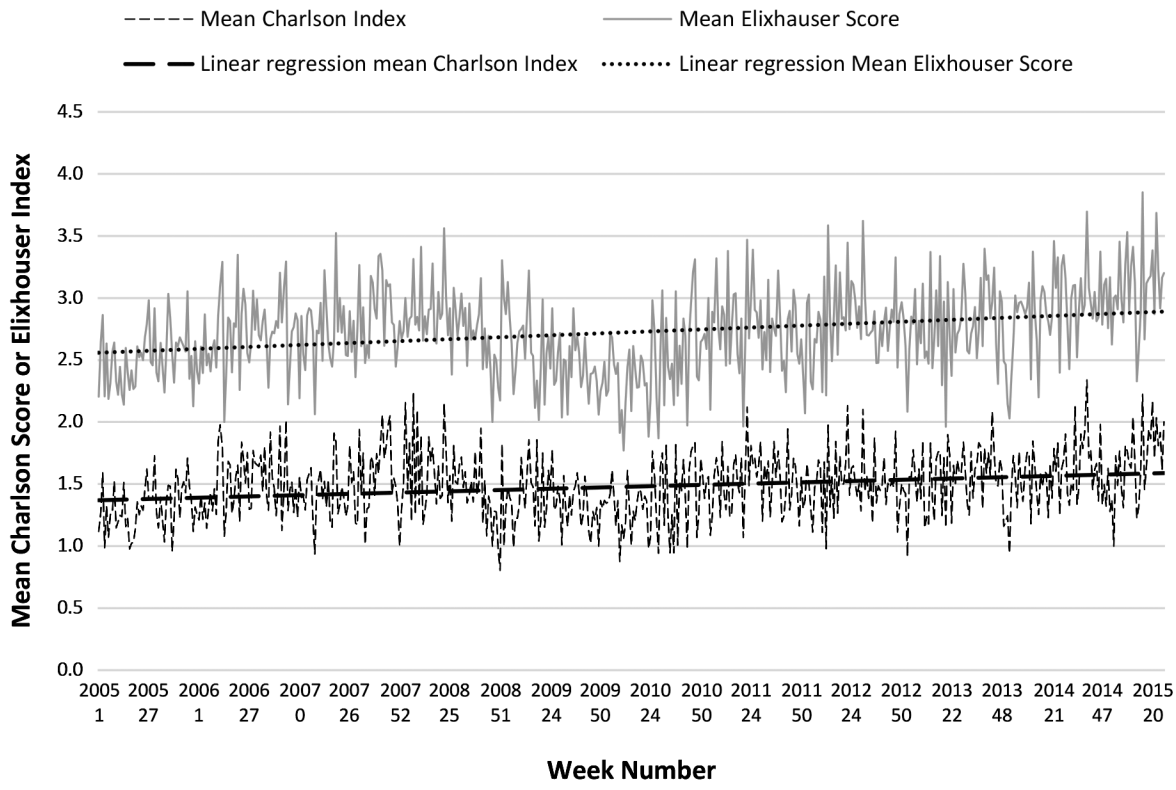
* = race distribution collapsed into two categories: white and non-white.

nonbreathing sleep-related disorders such as parasomnias.[20,21] Our data indicate that over time there has been an increase in the medical complexity of the patients studied in our sleep center. This could be for a variety of reasons. We had posited that as less complicated patients receive HSAT for the diagnosis of OSA, that more complicated patients would aggregate into our sleep center. This seems likely. However, although there was a nearly 500% increase in use of HSAT at our facility during this period, HSAT made up a very small volume (< 5%) of overall tests performed during the study period. Our results might be anticipated to show even higher rises in complexity in communities with faster growth in HSAT utilization. Because we are unable to discern the influence of HSAT utilization by referring communities on our sleep center population, we must consider alternative explanations for the increase in comorbidity at our sleep center.

Other studies have suggested significant increases in the prevalence of chronic diseases in more general patient

Downloaded from jcsm.aasm.org by 129.176.151.19 on December 10, 2020. For personal use only. No other uses without permission.
Copyright 2020 American Academy of Sleep Medicine. All rights reserved.

Figure 2—Slope of the Charlson comorbidity and Elixhauser index over a 10-year period.



Charlson index regression: y = 0.02938 x + 57.464, R^2 = 0.0016; Elixhauser Index regression: y = 0.04546 x + 88.488, R^2 = 0.0027.

Table 3—Percent of patients with individual comorbidities overall and for the first and last year, sorted in descending order of change in prevalence over time.

Comorbidity	Overall (%)	First Year 2005 (%)	Last Year 2015 (%)	Change Per Year (Slope)	Trend Test Over Months (*P*)
Peripheral vascular disease	15.64	11.21	21.60	.981	< .001
Moderate/severe renal disease	7.14	3.50	9.09	.438	< .001
Mild liver disease	7.78	5.96	10.02	.276	< .001
Dementia	3.61	2.00	4.64	.245	< .001
Myocardial infarction	4.91	3.70	5.80	.125	< .001
Congestive heart failure	11.85	10.55	14.39	.111	.070
Cerebrovascular disease	8.44	7.99	9.46	.084	.077
Hemiplegia	1.24	1.29	1.75	.077	< .001
Rheumatologic disease	3.57	3.70	3.95	.066	.030
Other cancer	10.28	8.80	10.73	.029	.584
Moderate/severe liver disease	0.66	0.68	0.98	.018	.235
Metastatic solid tumor	1.91	1.45	2.20	.010	.679
AIDS	0.05	0.00	0.11	.008	.072
Ulcer	1.63	1.78	1.59	−.011	.599
Diabetes	19.80	19.60	20.06	−.042	.526
Diabetes with organ damage	4.96	5.40	4.98	−.047	.224
Chronic pulmonary disease	20.60	22.06	21.38	−.051	.475

Values are presented as the percent of the sample that had the comorbidity.

populations. However, this general trend would not change the conclusion of our study that patient comorbidity has increased in the sleep study population.[22,23] It is also likely that more conditions are being diagnosed because of better and improved testing, medical care, and documentation of diagnoses.[24] Further research might look into similar profiles for patients being

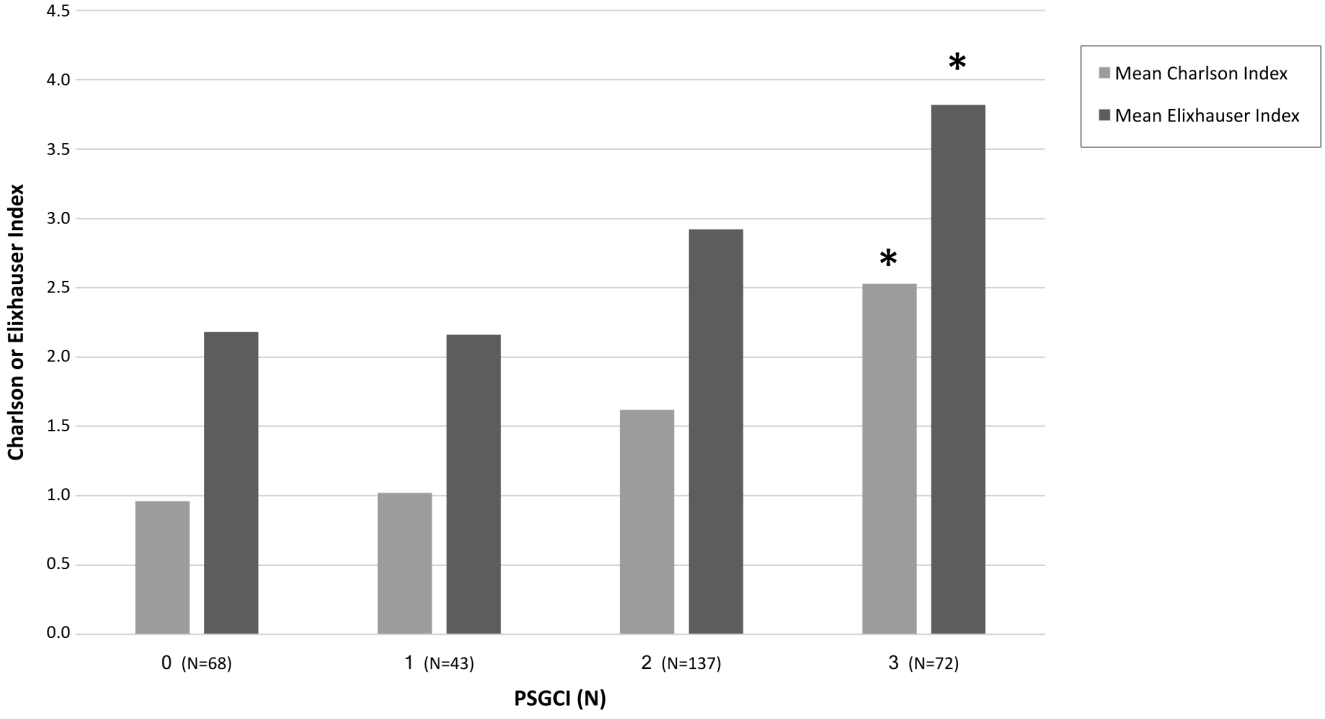
Downloaded from jcsm.aasm.org by 129.176.151.19 on December 10, 2020. For personal use only. No other uses without permission.
Copyright 2020 American Academy of Sleep Medicine. All rights reserved.

Table 4—PSGCI score compared with Charlson and Elixhauser mean indices for subset 320 patients over a 2-month period.

PSGCI Score	Number	% of Total	Mean Charlson Index	Mean Elixhauser Index
0	68	21.25%	0.96	2.18
1	43	13.44%	1.02	2.16
2	137	42.81%	1.62	2.92
3	72	22.50%	2.53	3.82

PSGCI = Polysomnogram Clinical Index.

Figure 3—Mean Charlson and Elixhauser indices at different PSGCI values.



* = $P < .001$ compared with index values for PSGCI = 0, 1, or 2. PSGCI = Polysomnogram Clinical Index.

studied with home sleep apnea tests to corroborate or provide alternative interpretations of these results.

We also considered that demographics changed over the studied interval. With an aging population, one might expect that there would be an associated increase in comorbidity. However, even though we saw statistically significant differences in patient demographics (age, race, BMI, and sex), a regression analysis adjusting for these factors still demonstrated a significant increase in comorbidity burden with both Charlson and Elixhauser indices. One noteworthy finding was a decline in BMI over the interval during a time when national BMI was increasing.

We gathered the PSGCI data for a period of 1 month for patients studied in the laboratory and found that patients with the highest PSGCI had significantly higher comorbidity indices (**Figure 3**). The PSGCI is a practical tool developed to assist us in anticipating staffing needs and room assignment during polysomnography operations. We have found that patients who require assistance to reduce risk of falls, who require assistance from a caregiver for emotional, behavioral, or clinical reasons, or those who require extra monitoring or therapeutic interventions, require greater personal attention from our technologists, and often require special equipment such as lift assist devices. Although the PSGCI utilizes information from the polysomnography order set to anticipate staffing and care requirements, one of the inherent limitations is that this score will miss any pertinent clinical detail not captured in the order set. However, using medical diagnoses or comorbidity indexes alone to anticipate needs has limitations as well, because it is not clear that the patient's comorbidities translate directly into the need for extra care such as fall precautions or other assistance. We think that a practical score such as the PSGCI has more application in the day-to-day operations of a sleep laboratory than do other indices based on historical data.

We also examined sleep study complexity over time based on clinical assessment of the type of study protocol and the type of positive pressure airway therapy used (**Table 1**). This measure also increased over time, supporting our hypothesis. In addition, this rating correlated with the PSGCI, thereby providing some validation to that index. One potential limitation with this aspect of our analyses is the underlying assumption that a study that used different types of PAP therapy was a

Downloaded from jcsm.aasm.org by 129.176.151.19 on December 10, 2020. For personal use only. No other uses without permission.
Copyright 2020 American Academy of Sleep Medicine. All rights reserved.

more complicated study than a diagnostic-only study, which may not always be true. Further study protocols are modified based on the instructions from the ordering provider and hence it is conceivable that a pulmonologist may order a study involving a more complex PAP titration, whereas a neurologist may involve a study with a more detailed parasomnia protocol. Hence, the complexity of studies may vary depending on the type of providers requesting the study. Because we are a multispecialty provider group, this may be a significant limitation.

Our research has several other limitations. We used data from the Mayo Clinic Center for Sleep Medicine, which is associated with a tertiary care academic medical center. Although over one-third of patients evaluated in the sleep center come from our employee and community populations, we are a regional, national, and international referral center. These same data may not be generalizable to smaller academic laboratories or nonacademic community sleep laboratories. Our patient demographics may also differ from that of other sleep laboratories. Another factor to consider is whether the indications for polysomnography might have changed over the study interval. The Center for Sleep Medicine is accredited by the AASM, which required adhering to practice guidelines of that organization. Indications for polysomnography did not change over that interval either in guideline or in practice at our institution. It is also not possible to discern whether a driving factor of increasing complexity of sleep center patients relates to changes in the overall complexity of Mayo Clinic patients. However, if that were the case, it only provides a more proximal reason for why the patients seen in our sleep center have increased in complexity; the less complex are having their sleep issues addressed in their local communities. Another factor that could affect the generalizability of these results is insurance guidelines and insurance-mandated HSAT, which is a significant consideration in some United States populations.

Importance/Significance

This research has several important implications. Whether the reason is an increase in HSAT utilization or other causes, our results suggest that the complexity of patients at attended sleep centers has increased over the 10-year period. This has implications for sleep center protocols, and technical and staff requirements for patients, as well as for insurance companies and health care systems that set reimbursement policies based on patient mixes. First, if the complexity of patients being studied in the sleep laboratory is increasing, our practice model for sleep laboratories will require modification to accommodate these complex patients. These changes will include increasing the clinical capabilities of sleep laboratories and addressing training and staffing needs. Currently the AASM guidelines recommend a 2:1 staffing ratio for technologists and patients. With increasing financial pressures, it will be helpful to be able to predict staffing needs reliably so that sleep laboratories are not overstaffed or understaffed, on a given night. For example, under some circumstances, low complexity patients may be appropriate for a 3:1 technologist ratio or employment of less extensively trained or experienced technologists. At the other extreme, for some patients a 1:1 ratio or employment of more highly trained nighttime health care workers, or testing in a setting other than the ambulatory sleep laboratory, may be required for a safe and successful sleep study. Sleep laboratories may need specialized equipment in the form of patient lifts, large beds with special hospital bed-like features, and more trained clinical staff. Although all patients who are now studied with in-laboratory polysomnography may not need a greater level of care, some of them likely will.

Second, we believe that the development of an index that allows sleep laboratories to stratify patients at risk for greater technical and/or nursing care will help assist with tailoring staffing and/or equipment needs. Our first model for this index, the PSGCI, is computed from the order set for a polysomnography ahead of the patient's study in the laboratory. It appears that reviewing the order in advance of the scheduled sleep study may allow the laboratory manager to determine what level of staffing the patient is likely to need for the night of his or her sleep study. Some patients may need 1:1 technologist to patient staffing, whereas others may need some clinical care through the night. Further refinement of equipment needs likely depends on other clinical factors, such as mobility, need for assistance, or behavioral care needs. Although the current policy in most sleep laboratories is not to provide clinical care, this may need to change to continue to deliver high-quality studies and be focused on patients who may have needs that exceed those of prior predominantly ambulatory patients.

From a cost, quality, and access standpoint, this research has far-reaching implications. From a cost standpoint, attended in-laboratory polysomnography will likely become more expensive to health care systems and these costs will be passed on to insurance companies and patients. Insurance companies and Medicare set the reimbursement for most tests using complicated algorithms that account for technical skill, facilities, and clinical and technical staffing and expertise required for the test, as well as the patient mix. Given our results, the reimbursement models for in-laboratory polysomnography may need to be revisited. From a quality standpoint, our research could be extrapolated to argue that to ensure high-quality polysomnography tests for the complex patients now being stratified to in-laboratory studies, sleep centers need to revisit their staffing and clinical capabilities and make adjustments. Finally, from an access standpoint, few laboratories will be financially viable to stay afloat with the increasing technical and clinical requirements of the laboratory, making access more difficult for patients. This may relegate in-laboratory polysomnography testing to tertiary and academic medical sleep laboratories, necessitating the consolidation of smaller sleep laboratories.

CONCLUSIONS

Our analyses show that the medical complexity of patients being studied with attended in-laboratory polysomnography over a 10-year period in the Mayo Clinic Center for Sleep Medicine has increased. This increased complexity could be secondary to the fact that patients with high pretest probability of sleep apnea and a low comorbidity profile are being studied with HSAT. Currently there is no single score that captures

Downloaded from jcsm.aasm.org by 129.176.151.19 on December 10, 2020. For personal use only. No other uses without permission.
Copyright 2020 American Academy of Sleep Medicine. All rights reserved.

the complexity of patients to anticipate the degree and level of care a patient might need for their sleep study. However, the PSGCI currently being used in the Center for Sleep Medicine correlates with other comorbidity indices and may help predict staffing and equipment needs.

ABBREVIATIONS

AASM, American Academy of Sleep Medicine
BMI, body mass index
CPT, Current Procedural Terminology
HSAT, home sleep apnea test
ICD, International Classification of Diseases
OSA, obstructive sleep apnea
PSGCI, Polysomnogram Clinical Index

REFERENCES

1. Collop NA, Anderson WM, Boehlecke B, et al. Clinical guidelines for the use of unattended portable monitors in the diagnosis of obstructive sleep apnea in adult patients. Portable Monitoring Task Force of the American Academy of Sleep Medicine. *J Clin Sleep Med.* 2007;3(7):737–747.
2. Kim RD, Kapur VK, Redline-Bruch J, et al. An economic evaluation of home versus laboratory-based diagnosis of obstructive sleep apnea. *Sleep.* 2015;38(7):1027–1037.
3. Parish JM, Freedman NS, Manaker S. Evolution in reimbursement for sleep studies and sleep centers. *Chest.* 2015;147(3):600–606.
4. Sleep Facility Accreditation. Standards for Accreditation (pdf). American Academy of Sleep Medicine website. https://aasm.org/accreditation/facility-accreditation/. Published November 2016. Accessed November 19, 2016.
5. Fragala G. Reducing occupational risk to ambulatory caregivers. *Workplace Health Saf.* 2016;64(9):414–419.
6. Hignet S, Griffiths P. Manual handling risks in the bariatric (obese) patient pathway in acute sector, community and ambulance care and treatment. *Work.* 2009;33(2):175–180.
7. Kolla BP, Lam E, Olson E, Morgenthaler T. Patient safety incidents during overnight polysomnography: a five-year observational cohort study. *J Clin Sleep Med.* 2013;9(11):1201–1205.
8. Grant RW, Ashburner JM, Hong CS, Chang Y, Barry MJ, Atlas SJ. Defining patient complexity from the primary care physician's perspective: a cohort study. *Ann Intern Med.* 2011;155(12):797–804.
9. Zulman DM, Asch SM, Martins SB, Kerr EA, Hoffman BB, Goldstein MK. Quality of care for patients with multiple chronic conditions: the role of comorbidity interrelatedness. *J Gen Intern Med.* 2014;29(3):529–537.
10. Loeb DF, Binswanger IA, Candrian C, Bayliss EA. Primary care physician insights into a typology of the complex patient in primary care. *Ann Fam Med.* 2015;13(5):451–455.
11. Grembowski D, Schaefer J, Johnson KE, et al. A conceptual model of the role of complexity in the care of patients with multiple chronic conditions. *Med Care.* 2014;52 Suppl 3:S7–S14.
12. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis.* 1987;40(5):373–383.
13. Roffman CE, Buchanan J, Allison GT. Charlson comorbidities index. *J Physiother.* 2016;62(3):171.
14. Charlson ME, Charlson RE, Peterson JC, Marinopoulos SS, Briggs WM, Hollenberg JP. The Charlson comorbidity index is adapted to predict costs of chronic disease in primary care patients. *J Clin Epidemiol.* 2008;61(12):1234–1240.
15. Elixhauser A, Steiner C, Harris DR, Coffey RM. Comorbidity measures for use with administrative data. *Med Care.* 1998;36(1):8–27.
16. Quan H, Sundararajan V, Halfon P, et al. Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. *Med Care.* 2005;43(11):1130–1139.
17. Agency for Healthcare Research and Quality. Statistical Brief #86. Healthcare Cost and Utilization Project (HCUP) website. http://www.hcup-us.ahrq.gov/reports/statbriefs/sb86.jsp. Published February 2010. Accessed December 21, 2011.
18. van Walraven C, Austin PC, Jennings A, Quan H, Forster AJ. A modification of the Elixhauser comorbidity measures into a point system for hospital death using administrative data. *Med Care.* 2009;47(6):626–633.
19. Weiss KB. Managing complexity in chronic care: an overview of the VA state-of-the-art (SOTA) conference. *J Gen Intern Med.* 2007;22 Suppl 3:374–378.
20. Pretto JJ, Gyulay SG, Hensley MJ. Trends in anthropometry and severity of sleep-disordered breathing over two decades of diagnostic sleep studies in an Australian adult sleep laboratory. *Med J Aust.* 2010;193(4):213–216.
21. Banno K, Walld R, Kryger MH. Increasing obesity trends in patients with sleep-disordered breathing referred to a sleep disorders center. *J Clin Sleep Med.* 2005;1(4):364–366.
22. Uijen AA, van de Lisdonk EH. Multimorbidity in primary care: prevalence and trend over the last 20 years. *Eur J Gen Pract.* 2008;14 Suppl 1:28–32.
23. Tacken MA, Opstelten W, Vossen I, et al. [Increased multimorbidity in patients in general practice in the period 2003-2009]. *Ned Tijdschr Geneeskd.* 2011;155(26):A3109.
24. Momin SR, Lorenz RR, Lamarre ED. Effect of a Documentation Improvement Program for an Academic Otolaryngology Practice. *JAMA Otolaryngol Head Neck Surg.* 2016;142(6):533–537.

ACKNOWLEDGMENTS

The authors thank Bonnie Robertson, CRT, RPSGT, who first shared a vision for developing an index of clinical complexity to be used in determining staffing requirements for attended polysomnography.

SUBMISSION & CORRESPONDENCE INFORMATION

Submitted for publication September 6, 2017
Submitted in final revised form December 14, 2017
Accepted for publication January 8, 2018
Address correspondence to: Timothy I. Morgenthaler, MD, FAASM, Mayo Clinic Center for Sleep Medicine, Mayo Clinic, 200 First Street SW, Rochester, MN 55905; Email: tmorgenthaler@mayo.edu

DISCLOSURE STATEMENT

All authors have seen and approve this manuscript. Brendon Colaco, Danial Herold, Matthew Johnson, Daniel Roellinger, James Naessens, and Timothy Morgenthaler have received no financial support for this work. Matthew Johnson, Daniel Roellinger, and James Naessens have no conflicts of interest to disclose. Brendon Colaco and Timothy Morgenthaler are practicing sleep specialist physicians, and Daniel Herold is a sleep technologist, who care for patients in a sleep center, but otherwise have no financial interests to disclose.

Downloaded from jcsm.aasm.org by 129.176.151.19 on December 10, 2020. For personal use only. No other uses without permission.
Copyright 2020 American Academy of Sleep Medicine. All rights reserved.