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Sleep testing during the pandemic

Adam C. Powell a,*, Logan M. Horrall a, James W. Long b, Amit K. Gupta a, Demian Gitnacht b

a HealthHelp, 16945 Northchase Drive, Suite 1300, Houston, TX, 77060, USA
b Humana Inc., 500 W. Main St., Louisville, KY, 40202, USA

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Abstract

Background: The COVID-19 pandemic disrupted the U.S. healthcare system, reducing the capacity available for unrelated conditions, such as sleep disordered breathing, and increasing concerns about the safety of in-lab testing. This study characterizes how the pandemic impacted the assessment of sleep disordered breathing and use of associated services.

Methods: Sleep testing claims occurring between January 2019 and June 2021 were extracted from the database of a national healthcare organization. Utilization was trended. Logistic regressions were run to assess the association between quarter of initial testing, whether testing was followed by treatment, and whether testing was followed by a clinical visit with a diagnosis related to sleep apnea, after controlling for patient-related factors. A Cox proportional hazards model assessed factors influencing time to treatment. Finally, a logistic regression assessed factors influencing the finality of home-based testing.

Results: In Q2 2021, home-based testing utilization was 134% of its initial level, while in-lab and split night testing were both at 61% of initial levels. Patients receiving initial home-based testing did not significantly differ in their likelihood of treatment, but were significantly less likely to have a clinical visit for sleep apnea (P < 0.01). Patients initially tested in 2021 were treated significantly more quickly than those initially tested in Q1 2019. Home-based testing occurring in Q4 2019 or later was significantly more likely to be definitive than home-based testing occurring Q1 2019.

Conclusions: Home-based sleep testing increased significantly and durably in 2020, and was associated with faster time to treatment than initial in-lab testing.

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1. Introduction

There is a high degree of overlap between the population most at risk for poor COVID-19 outcomes and the population most at risk for sleep disordered breathing [1]. Diabetes, hypertension, and obesity are associated with both obstructive sleep apnea and death due to COVID-19 [2]. While patients with obstructive sleep apnea are not at higher risk for contracting COVID-19, they are at higher risk for hospitalization than patients without obstructive sleep apnea [3]. Sleep tests and interventions are particularly dangerous in the context of COVID-19, as they have the potential to generate aerosols and droplets, which are the primary means by which COVID-19 spreads [4].

The danger of sleep testing was perceived as so great that one author declared in April 2020 that “in a pandemic situation, especially in the mitigation or suppression phases/strategies, sleep labs should no longer be working on diagnosis” [5]. One survey of sleep testing laboratories revealed there was a near cessation of in-lab sleep studies at the height of the pandemic [6]. This cessation was congruent with federal policy, as on March 18th, 2020, the Centers for Medicare & Medicaid Services (CMS) recommended all non-essential medical, surgical, and dental procedures be delayed to preserve access to personal protective equipment, beds, and ventilators [7]. As a consequence of this drastic reduction in in-lab testing, greater use of home-based testing was one compensatory strategy that was implemented [8].

This study aimed to characterize how testing and treatment for sleep disordered breathing changed between January 2019 and June 2021 because of the pandemic. Using claims data from a national healthcare organization offering commercial and Medicare Advantage health plans, the study examined how utilization of in-lab and home-based sleep testing evolved during this pivotal period.
period at a population level. As concerns over COVID-19 may have led some patients straight to treatment following home-based testing, rather than to have an in-lab follow-up test, the study additionally examined the trend in the rate at which home-based tests were followed by additional testing at a population level.

2. Methods

2.1. Study design

This study was reviewed by the Advarra institutional review board (Pro00061240), and received an exemption from oversight on February 14th, 2022, in accordance with the Department of Health and Human Services regulations found at 45 CFR 46.104(d)(4). The study was conducted in accordance with the principles of the Declaration of Helsinki.

2.2. Data source and sample population

Claims for sleep testing occurring between January 1st, 2019 and June 30th, 2021 were extracted from the database of a national healthcare organization (See Table A1 in the Appendix for the Current Procedural Terminology codes used to define the variables in this study.). Claims related to home-based and in-lab testing for sleep disordered breathing; patients receiving in-lab split night tests as their initial sleep test were categorized separately from patients receiving initial in-lab testing without the initiation of continuous positive airway pressure therapy or bilevel ventilation. The patients receiving the care were adults with commercial and Medicare Advantage health plans. Claims were excluded from the sample if they pertained to patients that were minors or over the age of 89. Additional exclusions were made for claims pertaining to patients without continuous enrollment 180 days prior to 60 days post the index event; initial sleep testing.

After this set of index claims was extracted, the patients’ claims in the 60 days followed these index claims were extracted to determine if the patients had claims for treatment of sleep disordered breathing or clinical visits mentioning a diagnosis related to sleep apnea (see Table A2 in the Appendix). The claims occurring in the 60 days following index claims for home-based sleep testing were reviewed to determine whether patients had any follow-on testing.

2.3. Measurement

2.3.1. Population-level analysis

The number of people with health plans eligible for inclusion in the study was determined for each month, January 2019 through June 2021. For each month, the number of claims for in-lab (not split night), in-lab (split night), and home-based sleep studies was determined. The number of home-based sleep study claims followed by an in-lab study claim within 60 days was also determined.

2.3.2. Individual-level analysis

The index event of the individual analysis was the patient’s initial sleep test claim. Claims in the 60 days following the index event were observed to determine values for the dependent variables: whether testing was followed by treatment within 60 days, whether testing was followed by a clinical visit related to sleep apnea within 60 days, the time elapsed between initial testing and treatment, and whether home-based testing was followed by in-lab or split night testing among the patients that had their initial test at home. The independent variable used in the individual-level analysis was the quarter in which the initial sleep test claim occurred.

A series of control variables were constructed to account for individual and social factors that may have influenced care. A set of categorical variables was generated to capture patient age (18–29, 30–39, 40–49, 50–59, 60–64, 65–69, 70–79, 80–89). The urbanicities and median incomes of the patients’ ZIP codes were determined, as urbanicity and income both have the potential to influence access to care. A table produced by CMS was used to map ZIP codes to their respective urbanicities [9]. ZIP codes were additionally mapped to their respective median incomes using the American Community Survey’s 2015–2019 five-year estimates, which reported income in 2019 inflation-adjusted dollars [10]. Two binary variables related to income were created; one capturing ZIP codes with median incomes < $40,000 per year, and the other capturing median incomes > $80,000 per year. Categorical variables were created to capture the region in which patients resided, using the definition of regions created by CMS [1]:]. Furthermore, all sleep apnea-related diagnosis codes observed in claims filed in the 60 days following the index event were noted and captured through binary variables which were used as control variables in the model examining factors influencing time to treatment. A categorical variable capturing the Current Procedural Terminology code used for initial home testing was created for use in the model examining factors associated with the finality of home-based testing.

2.4. Analysis

2.4.1. Population-level analysis

Month-by-month sleep testing utilization by type of testing (home-based, in-lab [not split night], or split night) was determined. The three types of testing were summed each month to determine total sleep testing utilization. Additionally, month-by-month utilization of home-based sleep testing that was followed by in-lab sleep testing within 60 days was determined. Month-by-month, for each outcome, the number of claims was divided by the number of people with health plans eligible for inclusion in the study in order to account for fluctuations in health plan enrollment. Utilization rates were normalized by dividing each month’s value by the level of utilization that occurred in January 2019. Spearman’s rank correlation was used to determine whether each of the trends was monotonic.

2.4.2. Individual-level analysis

Descriptive statistics were reported, stratified by year of initial sleep test. Multivariable logistic regressions were run to determine the association between the quarter of initial testing, the control variables, and two outcomes: whether initial testing was followed by treatment within 60 days, and whether initial testing was followed by a clinical visit with a diagnosis related to sleep apnea within 60 days. The control variables in these analyses were age, urbanicity, median income in patient’s home ZIP code, patient’s region, patient’s sex, line of business of patient’s health plan, and the type of initial sleep test received by the patient. Results were presented as odds ratios (OR) with 95% confidence intervals (CI), along with P values.

To determine the factors that impacted time to initial non-
medical treatment, a Cox proportional hazards model was run, with days from initial testing to treatment serving as the dependent variable. Patients that did not have a claim for treatment within 60 days were treated as censored observations, with no treatment having occurred during the observation window of 0–60 days. As this model focused on patients that had received treatment, patients’ diagnoses related to sleep apnea were included as control variables. Adjusted hazard ratios (HR) were reported with 95% CIs and P values.

Considering only the subset of the population that initially received home-based testing, a multivariable logistic regression was run to assess the association between quarter of initial testing and whether the initial home-based testing was final. The dependent variable was coded so that patients without any follow-on testing were coded as having had a ‘1’ outcome, and patients with follow-on testing were coded as having had a ‘0’ outcome. Additional control variables were added, capturing the Current Procedural Terminology (CPT) code of the initial home-based test, with the most common code (G0399) serving as the reference value. The CPT code used to bill for the initial home-based test was included as a control variable, as it is possible that not all home-based tests are equally likely to be followed by further testing.

3. Results

3.1. Population-level trends

As is shown in Fig. 1, total utilization of sleep testing in June 2021 was only 85% of the January 2019 level. Virtually no in-lab sleep testing occurred in April 2020. By June 2021, home-based sleep testing was at 134% of its January 2019 level. However, the number of home-based tests that were followed by in-lab tests within 60 days were only 74% of the January 2019 level. Although in-lab and split night testing rebounded somewhat in 2021, they both remained at 61% of their January 2019 utilization levels in June 2021. Spearman’s rank correlation found a significant association between month and normalized utilization of total testing (rho = −0.64; P < 0.01), initial lab-based testing (rho = −0.73; P < 0.01), and split night testing (rho = −0.74; P < 0.01), but not home-based testing (rho = 0.30; P = 0.11) or home-based testing followed by in-lab testing (rho = −0.33; P = 0.08).

Fig. 1. Trends in sleep test utilization.
3.2. Individual-level analysis sample and descriptive statistics

A total of 169,484 claims for sleep studies met inclusion criteria for the study. After exclusion criteria were applied, 130,078 claims corresponding to index sleep testing events remained in the sample (Fig. 2). Of these claims, 55,295 (42.5%) corresponded to testing initiated in 2019, 47,975 (36.9%) to testing initiated in 2020, and 26,808 (20.6%) to testing initiated in 2021. As is shown in the descriptive statistics (Table 1), there was a significant shift ($P < 0.01$) in the type of initial testing over time. While in home testing accounted for only 40.5% of initial testing in 2019, it accounted for the majority of initial testing in 2021; 53.4%. There were significant differences ($P < 0.05$) over time for each of the control variables considered, with a few exceptions. There was not a significant shift in the proportion of tests conducted on individuals from communities with median incomes above $80,000 per year. Furthermore, the proportion of index claims that were followed by downstream claims mentioning diagnoses of other sleep apnea, Cheyne-Stokes breathing, central sleep apnea, complex sleep apnea, and obesity hypoventilation syndrome did not significantly change over time.

Two separate multivariable logistic regressions with the same covariates were run to assess the factors that influenced whether an index sleep testing claim was followed by treatment within 60 days or a clinical visit mentioning a diagnosis related to sleep apnea within 60 days (Table 2). The association between quarter of initial sleep testing and odds of treatment within 60 days following initial testing was assessed using a categorical variable, with the first quarter of 2019 serving as the reference value. The variable was significant for all quarters, except the fourth quarter of 2020. Initial testing conducted between the second quarter of 2019 and the first quarter of 2020, or during the second quarter of 2021, was associated with reduced odds of downstream treatment, relative to initial testing conducted in the first quarter of 2019. Meanwhile, initial testing conducted in the second or third quarter of 2020, or in the first quarter of 2021, was associated with increased odds of downstream treatment.

All categorical variables related to age were likewise significantly associated with the odds of treatment in the 60 days following testing, with patients aged 18 to 29 serving as the reference group. The odds of treatment following testing increased with age between ages 30 and 69, and then declined with age for subsequent age brackets. Living in a rural area (OR: 1.07; 95% CI: 1.04–1.11), living in a ZIP code with a median income below $40,000 per year (OR: 0.94), and being male (OR: 1.28; 95% CI: 1.25–1.31) were each significantly associated with odds of treatment within 60 days following testing. Region was likewise significantly associated with odds of treatment, with
Acronyms: CMS, Centers for Medicare & Medicaid Services; Q, quarter.

the direction of the effect varying by region. No association was found between the type of initial testing conducted and receiving treatment within 60 days of testing.

Relative to claims for initial testing from the first quarter of 2019, claims for initial testing from the third quarter of 2019 through the first quarter of 2020 were associated with significantly lower odds of a clinical visit mentioning a diagnosis of sleep apnea in the following 60 days. No association was found between age, urban- or city living in CMS Region 1. Patients living in CMS Region 3 (DC, DE, MD, PA, VA, WV) had relatively longer time to treatment than those whose initial test occurred in-lab or lab split night (OR: 0.85; 95% CI: 0.83-0.87).

An adjusted Cox proportional hazards model was used to evaluate the association between the covariates and days from initial testing to treatment, if any (Table 3). Relative to receiving initial testing in the first quarter of 2019, receiving initial testing in the fourth quarter of 2019 was associated with significantly longer time to treatment, and receiving initial testing in the first or second quarter of 2020 or the first or second quarter of 2021 was associated with significantly shorter time to treatment. Being older than age 18 to 29 was associated with significantly shorter time to treatment, with older age associated with increasingly faster time to treatment from ages 30 to 69, and then declining with further age. Patients living in rural areas had significantly shorter time to treatment (HR: 1.08, 95% CI: 1.06-1.11), as did male patients (HR: 1.12; 95% CI: 1.10-1.15). Patients living in ZIP codes with a median income below $40,000 per year had significantly longer time to treatment (HR: 0.97; 95% CI: 0.94-1.00). Patients living in CMS Region 3 (DC, DE, MD, PA, VA, WV) had relatively longer time to treatment than patients living in CMS Region 1 (CT, MA, ME, NH, RI, VT), and patients living in CMS Region 4 (AL, FL, GA, KY, MS, SC, TN) had relatively shorter time to treatment, relative to patients living in CMS Region 1. Patients whose initial test occurred in-lab had significantly longer time to treatment than those whose initial test occurred at home (HR: 0.85; 95% CI: 0.83-0.86), while patients whose initial test was a split night test had significantly shorter time to treatment (HR: 1.19; 95% CI: 1.06-1.33).

Additionally, claims in the 60 days following testing mentioning a diagnosis of obstructive sleep apnea were associated with significantly shorter time to treatment (HR: 40.64; 95% CI: 38.67-42.70, Table 3), as were claims mentioning a diagnosis of primary central sleep apnea (HR: 1.08; 95% CI: 1.02-1.15). Claims in the 60 days following testing mentioning a diagnosis of unspecified sleep apnea, primary central sleep apnea, other sleep apnea, Cheyne-Stokes breathing, central sleep apnea/complex sleep apnea, sleep related nonobstructive alveolar hypventilation, and snoring were associated with longer time to treatment.

Among patients receiving initial home-based testing, the odds
that there was no follow-up testing within 60 days were significantly higher if the initial testing occurred between the fourth quarter of 2019 and the second quarter of 2021, relative to the first quarter of 2019. Home-based initial testing was significantly more likely to not be followed by additional testing if the patient came from a ZIP code with median income above $80,000 (OR: 1.14; 95% CI: 1.06–1.22) or if the patient had a commercial health plan (OR: 1.08; 95% CI: 1.02–1.15). Residence in CMS Region 7 (IA, KS, MO, NE) was associated with significantly lower likelihood that initial home-based testing would not be followed by additional testing, relative to residence in CMS Region 1 (CT, MA, ME, NH, RI, VT) (OR: 0.94; 95% CI: 0.89–0.99). Initial home-based testing billed under Current Procedural Terminology codes 95800, 95806, and G0398 was significantly less likely to be final, relative to initial home-based testing billed under G0399.

4. Discussion

Collectively, these analyses provide an illustration of how sleep testing and treatment evolved during the pandemic within a privately insured population. While prior research has used survey data to examine how sleep center operations changed in response to the pandemic, this study is the first to examine how claims shifted as a consequence of these operational changes. The findings from this study affirm prior research demonstrating that lab-based sleep testing was severely impacted by the pandemic, and that a new era in which home-based testing plays a larger role has begun [1]. As laboratories reopen, there needs to be consideration of the fact that waves of the pandemic may recur and that home-based testing may be viable in more situations than had been considered in the past [12].

One potential cause of the durable shift in testing shown in this data may be a reduction in the availability of in-lab testing for sleep disordered breathing in response to the pandemic. A survey of United States Department of Veterans Affairs facilities found that in-lab sleep testing stopped at 91.1% of facilities during the pandemic, and ultimately, 76.5% of facilities resumed diagnostic studies, and 60.8% resumed titration studies by the time the survey was conducted in August through November 2020. Meanwhile, while 50.0% of the Veterans Affairs facilities reported having discontinued home sleep studies during the pandemic, by the time of the survey, all had resumed offering services [13]. The findings of this analysis suggest that there may be quality benefits to home-based testing. Although patients that received home-based testing did not significantly differ in their odds of receiving treatment relative to patients that received in-laboratory

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Table 3

Adjusted hazard ratios from Cox proportional hazards model examining time to initial treatment.

| HR (95% CI) | P Value |
|------------|---------|
| Timing: Q2 2019 (vs Q1 2019) | 0.97 (0.93–1.01) | 0.13 |
| Timing: Q3 2019 (vs Q1 2019) | 0.96 (0.92–1.00) | 0.05 |
| Timing: Q4 2019 (vs Q1 2019) | 0.90 (0.87–0.94) | <0.01 |
| Timing: Q1 2020 (vs Q1 2019) | 1.09 (1.04–1.13) | <0.01 |
| Timing: Q2 2020 (vs Q1 2019) | 1.16 (1.11–1.22) | <0.01 |
| Timing: Q3 2020 (vs Q1 2019) | 1.03 (0.99–1.08) | 0.10 |
| Timing: Q4 2020 (vs Q1 2019) | 0.99 (0.95–1.03) | 0.68 |
| Timing: Q1 2021 (vs Q1 2019) | 1.06 (1.02–1.10) | 0.01 |
| Timing: Q2 2021 (vs Q1 2019) | 1.20 (1.15–1.25) | <0.01 |

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Acronyms: CMS, Centers for Medicare & Medicaid Services; Dx, diagnosis; Q, quarter.
and split night testing, patients that had home-based testing were significantly less likely to have a clinical visit mentioning a diagnosis related to sleep apnea than were patients that initially received in-lab testing (Table 2). Furthermore, home-based testing was associated with significantly shorter time from initial testing to treatment than was initial in-lab, non-split night testing. As this shift occurs, ordering physicians may wish to consider that not all home-based and split night testing, patients that had home-based testing were significantly less likely to have a clinical visit mentioning a diagnosis related to sleep apnea than were patients that initially received in-lab testing (Table 2). Furthermore, home-based testing was associated with significantly shorter time from initial testing to treatment than was initial in-lab, non-split night testing. As this shift occurs, ordering physicians may wish to consider that not all home-based and split night testing, patients that had home-based testing were significantly less likely to have a clinical visit mentioning a diagnosis related to sleep apnea than were patients that initially received in-lab testing (Table 2). Furthermore, home-based testing was associated with significantly shorter time from initial testing to treatment than was initial in-lab, non-split night testing. As this shift occurs, ordering physicians may wish to consider that not all home-based and split night testing, patients that had home-based testing were significantly less likely to have a clinical visit mentioning a diagnosis related to sleep apnea than were patients that initially received in-lab testing (Table 2). Furthermore, home-based testing was associated with significantly shorter time from initial testing to treatment than was initial in-lab, non-split night testing. As this shift occurs, ordering physicians may wish to consider that not all home-based tests are equally-likely to be debugged. If the organization has changed its prevalence within the population [15]. In fact, the global prevalence of insomnia symptoms during the pandemic has been estimated to be potentially as high as 45% [16]. Future research should assess whether changes in the demographics of patients receiving sleep testing impacted outcomes following testing.

4.1. Limitations

There are a number of limitations to this study which need to be considered when interpreting the results. As the study only considered patients with commercial and Medicare Advantage health plans from one national healthcare organization. Thus, the findings are not reflective of other populations, such as people with Medicaid health plans or with health plans from other organizations in CMS Region 4 (AL, FL, GA, KY, MS, NC, SC, TN), as is shown in Table 1, its regional distribution is not reflective of the distribution of people across the United States. Lastly, due to the claims-based nature of the analysis, clinical outcomes were not considered by the study.

Table 4

| Table 4 | Adjusted odds ratios from multivariable logistic regression examining finality of home testing. |
| --- | --- |
| Description | OR (95% CI) | P Value |
| Timing: Q2 2019 (vs Q1 2019) | 1.06 (0.94–1.19) | 0.37 |
| Timing: Q3 2019 (vs Q1 2019) | 1.09 (0.97–1.22) | 0.16 |
| Timing: Q4 2019 (vs Q1 2019) | 1.29 (1.15–1.46) | <0.01 |
| Timing: Q1 2020 (vs Q1 2019) | 1.81 (1.59–2.07) | <0.01 |
| Timing: Q2 2020 (vs Q1 2019) | 1.79 (1.55–2.06) | <0.01 |
| Timing: Q3 2020 (vs Q1 2019) | 1.25 (1.12–1.41) | <0.01 |
| Timing: Q4 2020 (vs Q1 2019) | 1.41 (1.25–1.59) | <0.01 |
| Timing: Q1 2021 (vs Q1 2019) | 1.19 (1.06–1.34) | <0.01 |
| Timing: Q2 2021 (vs Q1 2019) | 1.52 (1.35–1.72) | <0.01 |
| Age: 30–39 (vs 18–29) | 1.30 (0.96–1.76) | 0.09 |
| Age: 40–49 (vs 18–29) | 1.15 (0.87–1.53) | 0.32 |
| Age: 50–59 (vs 18–29) | 1.08 (0.82–1.42) | 0.59 |
| Age: 60–64 (vs 18–29) | 1.12 (0.85–1.49) | 0.43 |
| Age: 65–69 (vs 18–29) | 1.06 (0.80–1.41) | 0.67 |
| Age: 70–79 (vs 18–29) | 1.13 (0.86–1.49) | 0.39 |
| Age: 80–89 (vs 18–29) | 1.11 (0.83–1.48) | 0.49 |
| Rural (vs Urban or Missing) | 0.99 (0.93–1.06) | 0.85 |
| ZIP Income: Below $40k (vs $40k–$80k) | 1.03 (0.95–1.12) | 0.45 |
| ZIP Income: Above $80k (vs $40k–$80k) | 1.14 (1.06–1.22) | <0.01 |
| CMS Region: 2 (NJ, NY) (vs Region 1) | 1.18 (0.78–1.77) | 0.44 |
| CMS Region: 3 (DC, DE, MD, PA, VA, WV) (vs Region 1) | 0.78 (0.54–1.12) | 0.18 |
| CMS Region: 4 (AL, FL, GA, KY, MS, NC, SC, TN) (vs Region 1) | 1.00 (0.70–1.43) | 1.00 |
| CMS Region: 5 (IL, IN, MI, MN, OH, WI) (vs Region 1) | 0.75 (0.53–1.07) | 0.12 |
| CMS Region: 6 (AR, LA, NM, OK, TX) (vs Region 1) | 0.85 (0.60–1.21) | 0.37 |
| CMS Region: 7 (IA, KS, MO, NE) (vs Region 1) | 0.67 (0.46–0.96) | 0.03 |
| CMS Region: 8 (CO, MT, ND, SD, UT, WV) (vs Region 1) | 0.71 (0.49–1.02) | 0.06 |
| CMS Region: 9 (AZ, CA, HI, NV) (vs Region 1) | 0.87 (0.75–1.55) | 0.69 |
| CMS Region: 10 (AK, ID, OR, WA) (vs Region 1) | 1.30 (0.87–1.94) | 0.20 |
| Male (vs Female or Unknown) | 0.87 (0.82–0.92) | <0.01 |
| Commercial (vs Medicare Advantage) | 1.46 (1.33–1.62) | <0.01 |
| Initial Home Testing: CPT 95800 (vs G0399) | 0.71 (0.65–0.78) | <0.01 |
| Initial Home Testing: CPT 95801 (vs G0399) | 0.66 (0.37–1.18) | 0.16 |
| Initial Home Testing: CPT 95806 (vs G0399) | 0.44 (0.42–0.47) | <0.01 |
| Initial Home Testing: CPT G0398 (vs G0399) | 0.60 (0.45–0.81) | <0.01 |
| Initial Home Testing: CPT G0400 (vs G0399) | 0.85 (0.68–1.05) | 0.13 |

Acronyms: CMS, Centers for Medicare & Medicaid Services; Q, quarter.
5. Conclusion

The COVID-19 pandemic profoundly changed sleep testing. Sleep testing utilization remained depressed between the onset of the pandemic and June 2021, and never recovered to the level observed in January 2019. After the onset of the pandemic, an increased number of sleep studies were performed in a home-based setting. This shift was durable, and home-based sleep testing continued to grow during the first half of 2021. Home-based testing was significantly more likely to be definitive after the onset of the pandemic. Concomitant with these shifts in testing patterns, receiving initial sleep testing in the first quarter of 2021, rather than the first quarter of 2019 was associated with faster time to treatment. Further research is needed to assess how the transformation of sleep testing has impacted long-term patient health.

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Appendix

### Table A1

| DESCRIPTION: | CODE: |
|--------------|-------|
| **Home-Based Sleep Testing** | |
| Sleep study, unattended simultaneous recording heart rate, oxygen saturation, respiratory analysis (e.g., by airflow or peripheral arterial tone), and sleep time | 95800 |
| Sleep study, unattended, simultaneous recording; minimum of heart rate, oxygen saturation and respiratory analysis (e.g., by airflow or peripheral arterial tone) | 95801 |
| Sleep study, unattended, simultaneous recording of heart rate, oxygen saturation, respiratory airflow, and respiratory effort (e.g., thoracoabdominal movement) | 95806 |
| Home sleep study with type II portable monitor, unattended; minimum of 7 channels: EEG, EOG, EMG, ECG/heart rate, airflow, respiratory effort and oxygen saturation | G0398 |
| Home sleep study with type III portable monitor, unattended; minimum of 4 channels: 2 respiratory movement/airflow, 1 ECG/heart rate and 1 oxygen saturation | G0399 |
| Home sleep study with type IV portable monitor, unattended; minimum of 3 channels | G0400 |
| **In-Lab Sleep Testing** | |
| Sleep study, simultaneous recording of ventilation, respiratory effort, ECG or heart rate, and oxygen saturation, attended by a technologist | 95807 |
| Polysomnography; any age, sleep staging with 1–3 additional parameters of sleep, attended by a technologist | 95808 |
| Polysomnography; age 6 years or older, sleep staging with 4 or more additional parameters of sleep, attended by a technologist | 95810 |
| **In-Lab Sleep Testing – Split Night** | |
| Polysomnography; age 6 years or older, sleep staging with 4 or more additional parameters of sleep, with initiation of continuous positive airway pressure therapy or bilevel ventilation, attended by a technologist | 95811 |
| **PAP Devices** | |
| Respiratory assist device, bi-level pressure capability, without back-up rate feature, used with non-invasive interface (nasal or facial mask) [BiPap] | E0470 |
| Respiratory assist device, bi-level pressure capability, with back-up rate feature, used with non-invasive interface (nasal or facial mask) [BiPap] | E0471 |
| Single level continuous positive airway pressure device or auto-titrating continuous positive airway pressure (CPAP if following a 95811, APAP otherwise) | E0601 |
| **Non-PAP Treatment** | |
| Humidifier, non-heated, used with positive airway pressure device | E0561 |
| Humidifier, heated, used with positive airway pressure device | E0562 |
| Oral device/appliance used to reduce upper airway collapsibility, adjustable or non-adjustable, prefabricated, includes fitting and adjustment | E0485 |
| Oral device/appliance used to reduce upper airway collapsibility, adjustable or non-adjustable, custom fabricated, includes fitting and adjustment | E0486 |
| Oral device/appliance used to reduce upper airway collapsibility, without fixed mechanical hinge, custom fabricated, includes fitting and adjustment | K1027 |

CRediT authorship contribution statement

Adam C. Powell: Conceptualization, Methodology, Investigation, Formal analysis, Visualization, Writing — original draft, Writing — review & editing. Logan M. Horrall: Conceptualization, Methodology, Software, Data curation, Writing — review & editing. James W. Long: Conceptualization, Methodology, Validation, Resources, Supervision, Project administration, Writing — review & editing. Amit K. Gupta: Conceptualization, Methodology, Validation, Writing — review & editing. Demian Gitnacht: Conceptualization, Methodology, Validation, Writing — review & editing.

Declaration of competing interest

AP, LH and AG report an employment or consulting relationship with HealthHelp/WNS. JL and DG report employment by Humana Inc. AP additionally reports employment by Payer + Provider Syndicate, and stock ownership of Amazon, Amgen, Google, Payer + Provider Syndicate, Pfizer, Target, and Walmart.

A.C. Powell, L.M. Horrall, J.W. Long et al. Sleep Medicine 101 (2023) 375–383
Table A2
ICD-10-CM Diagnosis Codes for Sleep Apnea

| DESCRIPTION                                           | CODE: |
|-------------------------------------------------------|-------|
| Sleep apnea, unspecified                              | G47.30|
| Primary central sleep apnea                           | G47.31|
| Obstructive sleep apnea (adult) (pediatric)           | G47.33|
| Other sleep apnea                                     | G47.39|
| Cheyne-Stokes breathing                               | R06.3 |
| Central sleep apnea/complex sleep apnea               | G47.37|
| Sleep related nonobstructive alveolar hypoventilation | G47.34|
| Obesity hypoventilation syndrome                      | E66.2 |
| Snoring                                                | R06.83|

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