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DIAGNOSTIC PITFALLS, POSITIONAL PHENOTYPING, AND TECHNICAL ARTIFACTS IN LEVEL 3 HOME SLEEP APNEA TESTING: A MULTICENTER COHORT STUDY OF 57-PATIENTS

Gowtham Kumar V[1], Prakash S[2], Dharmaraja Dakshinamoorthy[3]

[1]Assistant Professor, Department of TB & Respiratory Medicine, Arunai Medical College & Hospital, Tiruvannamalai, Tamilnadu, India.
[2]Assistant Professor, Department of TB & Respiratory Medicine, Arunai Medical College & Hospital, Tiruvannamalai, Tamilnadu, India.
[3]Assistant Professor, Department of ENT, Government Pudukkottai Medical College & Hospital, Pudukottai, Tamilnadu, India.

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Corresponding Author:
Dr. Gowtham Kumar V,
Email: gowthamkumar005@gmail.com

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ABSTRACT

Background: Level 3 home sleep apnea testing (HSAT) provides an accessible alternative to attended polysomnography for the evaluation of patients with suspected obstructive sleep apnea (OSA). However, the absence of electroencephalography (EEG), variability in recording quality, limited positional information, and device-specific reporting characteristics may affect diagnostic interpretation. This study evaluated diagnostic pitfalls, positional phenotypes, and technical artifacts encountered during routine Level 3 HSAT performed using two commonly used portable monitoring systems. **Materials and Methods:** A retrospective multicenter observational cohort of 57 consecutive adults evaluated for suspected OSA was analyzed. Twenty-one patients underwent testing using the BMC YH-600B and 36 using ResMed ApneaLink. Device-generated reports were reviewed for apnea–hypopnea index (AHI), oxygen desaturation index (ODI), nocturnal oxygen saturation characteristics, recording and flow-evaluation duration, body-position information where available, and snoring-event counts. Positional OSA was assessed using the Cartwright criterion and, where adequate positional information was available, the Amsterdam Positional OSA Classification. Four predefined diagnostic pitfalls were evaluated: short flow/evaluation periods, positional indeterminacy, paradoxical lateral-worse respiratory events, and acoustic–severity dissociation. **Results:** The mean AHI was 32.7 ± 26.2 events/h, with a range of 0.1–103.4 events/h. Severe OSA was identified in 25 (43.9%) patients, moderate OSA in 13 (22.8%), mild OSA in 11 (19.3%), and an AHI below 5 events/h in 8 (14.0%). Six patients (10.5%) demonstrated short flow/evaluation periods associated with potential denominator-related distortion of the AHI. Positional assessment was limited in 42 patients (73.7%), including six BMC YH-600B recordings with >90% of total sleep time spent supine and all 36 ResMed ApneaLink reports without posture-stratified data in the available reports. Three BMC studies fulfilled positional OSA criteria, while five patients demonstrated a paradoxical lateral-worse pattern. Acoustic–severity dissociation was identified in six patients (10.5%), with snoring burden showing substantial discordance from AHI. **Conclusion:** Level 3 HSAT is a valuable diagnostic tool for patients with suspected OSA, but automated AHI values should not be interpreted in isolation. Verification of technically valid flow duration, assessment of positional data availability, and recognition of discordant respiratory and acoustic findings are important for avoiding diagnostic misclassification. When technical adequacy or clinical interpretation remains uncertain, attended polysomnography should be considered.

INTRODUCTION

Obstructive sleep apnea (OSA) is one of the most common sleep-related breathing disorders in adults and represents an important public health problem because of its association with cardiovascular, metabolic, neurocognitive, and daytime functional consequences.[1,2] Despite its high prevalence, OSA

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remains substantially underdiagnosed, particularly in healthcare environments where access to attended laboratory polysomnography is limited. The increasing availability of portable monitoring has therefore expanded the diagnostic pathway for patients with a high pre-test probability of moderate-to-severe OSA.

Level 3 home sleep apnea testing (HSAT) systems generally record several physiological signals, including respiratory airflow, respiratory effort, and oxygen saturation, but do not incorporate EEG-based sleep staging.[3,4] Their principal advantage is that testing can be performed in the patient's usual sleeping environment with reduced cost, logistical burden, and resource requirements. Current clinical practice guidelines support HSAT in appropriately selected adults with an increased likelihood of uncomplicated moderate-to-severe OSA.[1]

However, the physiological simplification that makes HSAT practical also creates important interpretive limitations. In the absence of EEG, portable monitors cannot reliably distinguish sleep from wakefulness. Consequently, the respiratory event index may be calculated using recording time or a device-specific flow-evaluation period rather than true total sleep time. In patients with insomnia, prolonged wakefulness, fragmented sleep, or technically inadequate recordings, this may result in distortion of respiratory event frequency.[1,4,5]

A second limitation relates to positional phenotyping. Positional OSA is commonly defined by a substantially greater respiratory event burden in the supine position than in non-supine positions. The Cartwright criterion remains widely used, while more recent classification systems, including the Amsterdam Positional OSA Classification (APOC), attempt to provide greater phenotypic and therapeutic differentiation.[6-8] Identification of positional OSA can have direct clinical relevance because selected patients may benefit from positional therapy. Nevertheless, the ability to characterize this phenotype depends on reliable body-position recording and adequate exposure to different sleeping positions.

Device architecture and report configuration may therefore influence the amount of clinically useful information available to the interpreting physician. A device that provides posture-stratified respiratory indices permits a different level of phenotyping from a system or report that provides only an overall AHI. Similarly, automated snoring counts may provide additional information regarding upper-airway vibration but should not be interpreted as a direct surrogate for obstructive respiratory-event severity.

The present study evaluated 57 consecutive adults undergoing Level 3 HSAT using BMC YH-600B and ResMed ApneaLink systems. The objective was to characterize clinically relevant diagnostic pitfalls, examine the feasibility of positional phenotyping, and identify technical or physiological patterns that could lead to inappropriate interpretation of automated HSAT results.

MATERIALS AND METHODS

Study Design and Setting

This was a retrospective, multicenter observational cohort study of adult patients who underwent unattended Level 3 HSAT for suspected OSA. The study included 57 consecutive patients evaluated at the participating sleep and respiratory medicine centers. Two portable monitoring platforms were represented: BMC YH-600B (n=21) and ResMed ApneaLink (n=36).

The study was designed primarily to evaluate the interpretability and technical limitations of routine Level 3 HSAT reports, with particular emphasis on recording adequacy, positional information, and discordance between different physiological signals.

The study was conducted in accordance with the principles of the Declaration of Helsinki and applicable institutional requirements for retrospective research involving human participants.

Study Population

The study population consisted of consecutive adult patients referred for evaluation of suspected OSA who underwent Level 3 HSAT as part of routine clinical care.

Inclusion Criteria

Patients were eligible if they:

1. were adults aged ≥18 years;
2. underwent unattended Level 3 HSAT for suspected OSA;
3. had a device-generated diagnostic report available for review;
4. had an interpretable respiratory-flow and/or oximetry recording; and
5. had sufficient report information to permit assessment of the primary respiratory index.

Exclusion Criteria

Patients were excluded if:

1. the HSAT report was unavailable or incomplete to the extent that the primary respiratory data could not be interpreted;
2. the study had major technical failure preventing assessment of respiratory events; or
3. essential patient or recording information required for the predefined analysis was unavailable.

No patient was excluded solely because of the eventual OSA severity category.

HSAT Equipment and Recording Parameters

All patients underwent unattended Level 3 portable respiratory polygraphy using either the BMC YH-600B or ResMed ApneaLink system according to the equipment available at the participating center and the routine clinical pathway.

The analysis focused on parameters routinely generated by these systems, including:

- respiratory airflow;
- respiratory effort, where recorded;

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- pulse oximetry;
- respiratory event index/AHI as reported by the device;
- oxygen desaturation index (ODI);
- oxygen saturation nadir;
- time spent below 90% oxygen saturation, where available;
- total recording duration;
- valid flow/evaluation duration;
- body-position information, where available; and
- snoring-event counts.

Because Level 3 HSAT does not include standard EEG-based sleep staging, the respiratory event index reported by the device may be calculated using recording time or a device-specific evaluation period rather than objectively measured total sleep time. This distinction was considered during interpretation of short recordings.

Device-Specific Data Availability

Device characteristics were evaluated descriptively rather than as a formal head-to-head diagnostic accuracy comparison. The BMC YH-600B recordings available for analysis included a multi-axial posture channel, allowing identification of body position and, where adequate supine and non-supine exposure was available, comparison of positional respiratory indices.

For the ResMed ApneaLink group, the available PDF summary reports did not provide posture-stratified respiratory event rates. Therefore, conventional positional classification was not performed for these patients from the available reports. The absence of posture-stratified information was recorded as a positional-data limitation, rather than interpreted as evidence that the patients had non-positional OSA.

Assessment of Recording and Flow Adequacy

Total recording duration and device-reported valid flow/evaluation duration were reviewed separately.

A **short flow/evaluation period** was predefined as a technically available flow/evaluation period of less than 90 minutes for the diagnostic-pitfall analysis. Such recordings were flagged because a small absolute number of respiratory events may generate a disproportionately high or otherwise unstable hourly index when calculated over a very short denominator. The original duration of each flagged recording was retained in the case-level review.

OSA Severity Classification

OSA severity was classified using conventional AHI thresholds:

- **Normal:** AHI <5 events/h
- **Mild OSA:** AHI 5–14.9 events/h
- **Moderate OSA:** AHI 15–29.9 events/h
- **Severe OSA:** AHI ≥30 events/h.

The classification was based on the respiratory index reported by the respective HSAT system.

Positional Phenotyping

Positional respiratory behavior was assessed when adequate body-position and respiratory-event data were available.

Positional OSA was defined using the conventional Cartwright criterion, namely a supine AHI at least twice the non-supine AHI.[6] Where adequate positional granularity permitted further classification, patients were additionally assessed according to the Amsterdam Positional OSA Classification (APOC) framework.[7,8]

A recording was considered **positional indeterminate** when reliable comparison between supine and non-supine respiratory indices was not possible because of:

1. Absence of a posture channel;
2. Absence of posture-stratified respiratory indices in the available report; or
3. **In**sufficient non-supine sleep exposure.

For the BMC YH-600B subgroup, patients spending >90% of total sleep time in the supine position were specifically identified because the limited non-supine exposure substantially restricted assessment of positional dependence.

Definition of Paradoxical Postural Worsening

A paradoxical lateral-worse pattern was defined as a lateral-position AHI greater than the supine-position AHI in a patient with BMI ≥35 kg/m². This pattern was considered descriptive and was not assumed to represent a distinct pathophysiological phenotype without confirmatory polysomnographic assessment. Patients with insufficient positional exposure or unavailable position-specific respiratory indices were not classified under this category.

Assessment of Acoustic–Severity Dissociation

Snoring-event counts were reviewed as an additional signal generated by the HSAT systems.

Acoustic–severity dissociation was defined as a marked discrepancy between snoring-event burden and the reported AHI, including:

- relatively low snoring counts despite clinically relevant respiratory-event burden; or
- very high snoring counts despite a relatively low or moderate AHI.

Snoring burden was treated as a supplementary physiological signal and **was not used independently to diagnose or exclude OSA or upper-airway resistance syndrome**.

A high snoring count was not considered sufficient evidence for UARS because diagnosis of UARS generally requires assessment of respiratory effort and arousal-related phenomena that cannot be established from snoring counts alone.

Diagnostic-Pitfall Classification

Each HSAT report was systematically reviewed for four predefined diagnostic-pitfall categories:

Pitfall 1: Short Flow/Evaluation Period

A flow/evaluation period <90 minutes was considered potentially susceptible to denominator-related distortion of the respiratory index.

Pitfall 2: Positional Indeterminacy

This included recordings with either predominantly supine sleep that prevented adequate positional comparison or absent posture-stratified data in the available report.

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Pitfall 3: Paradoxical Lateral-Worse Pattern
This was defined as lateral AHI > supine AHI in patients with BMI ≥35 kg/m².
Pitfall 4: Acoustic–Severity Dissociation
This referred to marked discordance between reported snoring-event burden and AHI.
Clinical and Physiological Variables
Where available, patient-level clinical variables included age, sex, BMI, and relevant clinical characteristics recorded in the HSAT report or associated clinical documentation. Respiratory and oxygenation variables included AHI, ODI, oxygen saturation nadir, and time below 90% oxygen saturation where reported.
Statistical Analysis
Data were analyzed using descriptive statistical methods appropriate for a retrospective observational cohort. Continuous variables were expressed as mean ± standard deviation and range when appropriate. Categorical variables were expressed as frequencies and percentages.
Ethical Considerations
The study involved retrospective review of clinical HSAT reports and anonymized patient information. The study was commenced after the approval from Institutional Ethics Committee, Informed consent was obtained from all participants. Strict confidentiality was maintained while analyzing and presenting the data.
Reporting of Diagnostic Pitfalls
The diagnostic-pitfall analysis was performed at the individual-study level. Representative cases were selected to illustrate the principal technical or physiological patterns identified during report review.

RESULTS

Distribution of OSA Severity
Across the 57-patient cohort, the mean AHI was 32.7 ± 26.2 events/h, with a range of 0.1–103.4 events/h. Severe OSA was the most frequent diagnostic category, occurring in 25 (43.9%) patients. Moderate OSA was identified in 13 (22.8%), mild OSA in 11 (19.3%), while 8 (14.0%) patients had an AHI below 5 events/h.

Table 1: Distribution of Obstructive Sleep Apnea Severity in the 57-Patient Cohort

OSA severity category	Number (n)	Percentage (%)
Severe OSA (AHI ≥30 events/h)	25	43.9
Moderate OSA (AHI 15–29.9 events/h)	13	22.8
Mild OSA (AHI 5–14.9 events/h)	11	19.3
No OSA (AHI <5 events/h)	8	14.0
Total	**57**	**100.0**

Abbreviation: AHI, apnea–hypopnea index.
Device-Specific Positional Data Capture
The availability of posture-stratified information differed substantially between the two devices.

Table 2: Comparison of Positional Data Capture According to Device Type

Parameter	BMC YH-600B (n=21)	ResMed ApneaLink (n=36)
Posture channel available	Yes; multi-axial	No posture-stratified data in available report
Positional OSA candidates identified	3	Not classifiable from available report
Supine-only / indeterminate sleep	6 (28.6%)	36 (100%)
Paradoxical lateral-worse pattern	5	Not assessable

Among the BMC YH-600B recordings, three patients fulfilled criteria for positional OSA using the available positional data. However, six patients (28.6%) spent >90% of total sleep time in the supine position, limiting reliable comparison between supine and non-supine respiratory indices. In contrast, the available ResMed ApneaLink PDF reports did not provide posture-stratified event rates in any of the 36 patients.
Diagnostic Pitfalls
Four major categories of diagnostic pitfall were identified during systematic review of the 57 HSAT reports.

Table 3: Diagnostic Pitfalls Identified Across the 57 HSAT Studies

No.	Diagnostic pitfall	Number (%)	Representative cases
1	Short flow/evaluation period with potential denominator-related artifact	6 (10.5)	Case 10: 21 min, AHI 68.6/h; Case 26: 35 min, AHI 13.8/h; Case 53: 1 h 37 min, AHI 72.6/h
2	Positional indeterminacy due to predominantly supine sleep or absent posture channel	42 (73.7)	Six BMC patients with >90% TST supine; all 36 ResMed reports lacked posture stratification
3	Paradoxical postural worsening (lateral AHI > supine AHI, BMI ≥35 kg/m²)	5 (8.8)	Five patients with elevated BMI demonstrating greater lateral respiratory-event burden
4	Acoustic–severity dissociation	6 (10.5)	Case 19: AHI 13.9/h with ≤5 snores; Case 38: AHI 17.4/h; Case 47: 9,457 snores with AHI 2.2/h; Case 54: 11,128 snores with AHI 15.4/h

Note: Diagnostic-pitfall categories were descriptive and could overlap within individual patients; therefore, percentages are not expected to total 100%.

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DISCUSSION

The present multicenter cohort study demonstrates that Level 3 HSAT can provide clinically useful information across the spectrum of OSA severity but also highlights several important technical and interpretive limitations. In 57 consecutive patients, severe OSA was the predominant diagnostic category, while the principal findings of clinical relevance involved short evaluation periods, positional indeterminacy, paradoxical positional respiratory patterns, and discordance between snoring burden and respiratory-event frequency.

The mean AHI of 32.7 ± 26.2 events/h reflects a substantial burden of sleep-disordered breathing in the studied cohort. Severe OSA accounted for 43.9% of patients, while 22.8% had moderate OSA and 19.3% had mild OSA. This distribution is consistent with the clinical use of HSAT in patients referred because of suspected OSA and supports its utility as an accessible diagnostic modality in appropriately selected patients.[1,3]

Short Evaluation Periods and Denominator-Related Distortion

Six patients (10.5%) had short flow/evaluation periods identified during the technical audit. The potential problem arises from the denominator used to calculate an hourly respiratory-event index.

Unlike attended polysomnography, Level 3 HSAT does not routinely measure EEG-defined sleep time. Consequently, the respiratory index may be calculated using total recording time or a device-defined valid flow/evaluation period.[1,4,5] If the available evaluation period is very short, a relatively small number of respiratory events can produce a disproportionately high hourly value.

Case 10 illustrates this phenomenon, with 24 obstructive apneas occurring during a 21-minute recording and an automated AHI of 68.6 events/h. Similarly, eight events during a 35-minute evaluation period in Case 26 produced an AHI of 13.8 events/h. Case 53 showed an AHI of 72.6 events/h during a reported 1-hour-37-minute flow period.

These examples do not establish that the automatically calculated values were mathematically incorrect. Rather, they illustrate the importance of evaluating the **duration and quality of the signal underlying the calculated index**. A short recording may provide insufficient information about variability across different sleep periods and may not adequately represent the patient's habitual sleep.

The AASM diagnostic guideline emphasizes adequate technical quality and appropriate clinical selection when HSAT is used.[1] When a technically inadequate study produces a result that is inconsistent with the clinical presentation, repeat testing or attended polysomnography may be required.

Positional Phenotyping and the "Supine Trap"

Positional indeterminacy was the most frequent diagnostic limitation identified, occurring in 42 patients (73.7%). This included six BMC YH-600B recordings with >90% of total sleep time spent supine and all 36 ResMed ApneaLink reports without posture-stratified information in the available reports.

The distinction between **non-positional OSA** and **positional indeterminate OSA** is clinically important. A patient who spends almost the entire recording in the supine position has not necessarily demonstrated that their OSA persists during lateral sleep. Instead, there may simply be insufficient non-supine exposure to establish a meaningful comparison.

The BMC YH-600B, because of its multi-axial posture channel, allowed positional assessment in patients with adequate positional exposure. Three patients fulfilled criteria for positional OSA. Positional OSA is traditionally defined according to the Cartwright criterion, in which the supine AHI is at least twice the non-supine AHI.[6]

The clinical relevance of positional phenotyping is considerable because positional therapy can be an appropriate component of treatment for selected patients. Previous studies have shown that positional OSA represents a substantial proportion of patients referred for sleep evaluation, although reported prevalence varies according to the diagnostic definition used.[9,10] Positional patients have also been described as generally younger and less obese and may have less severe overall disease than patients with non-positional OSA.[9]

The APOC framework provides greater phenotypic differentiation than a simple binary positional/non-positional classification and may help identify patients with a greater potential therapeutic response.[7,8,11,12]

In the present cohort, however, the 36 ResMed ApneaLink reports did not provide posture-stratified respiratory event rates in the available PDF reports. Thus, the inability to classify positional OSA in these patients represents a **report-level information limitation**. It should not be interpreted as proof that the device is inherently incapable of recording body position in every configuration.

Paradoxical Lateral-Worse Respiratory Pattern

Five patients with BMI ≥35 kg/m² demonstrated a higher lateral than supine AHI. This finding is contrary to the commonly recognized pattern of supine worsening in OSA and illustrates the heterogeneity of positional respiratory physiology.

Positional effects on upper-airway patency are influenced by body habitus, airway anatomy, gravitational effects, and individual susceptibility. Although lateral positioning frequently reduces respiratory event burden, this protective effect is not universal. Previous research has suggested that normal BMI has a high negative predictive value for moderate-to-severe OSA in the lateral sleeping

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position, while obesity may diminish the protective effect of lateral positioning.[13]

Richard et al. similarly demonstrated that body position has an important but heterogeneous relationship with OSA severity.[14]

The five lateral-worse cases in the present study therefore highlight the importance of examining actual position-specific respiratory data before recommending positional therapy. A generalized assumption that lateral positioning will always improve OSA may be inappropriate in patients with substantial obesity or unusual upper-airway mechanics.

Acoustic–Severity Dissociation

Snoring-event counts demonstrated marked variability across the cohort, ranging from very low values to more than 11,000 events. Six patients demonstrated a clinically notable mismatch between acoustic snoring burden and AHI.

Cases 19 and 38 showed relatively low snoring counts despite clinically meaningful respiratory-event indices, whereas Cases 47 and 54 showed exceptionally high snoring counts despite relatively low-to-moderate AHI values.

These findings reinforce that snoring and obstructive respiratory events represent related but distinct physiological phenomena. Snoring reflects vibration of upper-airway tissues and may occur with partial narrowing without complete airflow cessation. Conversely, apneas and hypopneas may occur without prominent acoustic activity.

Accordingly, snoring counts should be regarded as a supplementary signal rather than a surrogate marker of OSA severity.

The original interpretation of Cases 47 and 54 as demonstrating UARS should also be approached cautiously. UARS was described by Guilleminault and colleagues as a disorder characterized by increased upper-airway resistance and respiratory-effort-related arousals associated with symptoms such as excessive daytime sleepiness.[15] Because Level 3 HSAT does not routinely provide EEG-based arousal assessment, the present data cannot independently establish UARS. The more appropriate interpretation is **acoustic–severity dissociation**, which may warrant further clinical assessment when symptoms and routine HSAT findings are discordant.

Surrogate Sleep Measurement and the Role of Polysomnography

The major advantage of Level 3 HSAT is its accessibility and relatively low resource requirement. It permits diagnostic evaluation in the patient's home environment and is particularly useful for patients with a high pre-test probability of uncomplicated moderate-to-severe OSA.[1,3]

Nevertheless, HSAT lacks several physiological signals available in laboratory polysomnography, particularly EEG-derived sleep staging. This limitation becomes important in patients with insomnia, prolonged wakefulness, uncertain sleep duration, or substantial clinical complexity.

Because HSAT may use recording or evaluation time rather than true sleep time as the denominator, respiratory indices may differ from PSG-derived AHI. This is one reason why a negative or technically inadequate HSAT should not necessarily exclude OSA in a patient with a high clinical suspicion [1].

Attended polysomnography remains particularly relevant when HSAT is technically inadequate, when there is a significant mismatch between symptoms and HSAT findings, or when another sleep disorder or complex sleep-related breathing disorder is suspected.[1,16]

Clinical Implications

The findings support a structured approach to interpretation of Level 3 HSAT reports.

First, clinicians should review the **duration of technically valid airflow and oximetry data** rather than relying exclusively on the displayed AHI.

Second, the **availability and adequacy of positional data** should be confirmed before diagnosing positional or non-positional OSA. Predominantly supine recordings should be recognized as potentially indeterminate.

Third, position-specific respiratory indices should be reviewed before recommending positional therapy, particularly in patients with obesity or atypical positional patterns.

Fourth, snoring-event counts should not be used independently to determine OSA severity or diagnose UARS.

Finally, when technical adequacy is questionable or clinical and HSAT findings are discordant, repeat HSAT or attended polysomnography should be considered.

The study also emphasizes that different HSAT platforms and report configurations may provide different levels of clinically useful phenotypic information. Therefore, clinicians should be familiar with the actual signals and indices exported by the device used in their practice.

Strengths of the Study

The principal strength of this study is its focus on the interpretive quality of routine HSAT reports rather than solely on the final diagnostic category. The analysis incorporated recording duration, positional information, body habitus, respiratory indices, and acoustic data.

The inclusion of two different Level 3 monitoring platforms also demonstrates how differences in available report information may influence phenotypic interpretation. In addition, representative cases illustrate practical situations in which an apparently straightforward automated report may require further clinical scrutiny.

CONCLUSION

Level 3 home sleep apnea testing is an effective and accessible diagnostic approach for appropriately selected patients with suspected obstructive sleep

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apnea. However, the present 57-patient cohort demonstrates that interpretation of HSAT requires more than reviewing the automatically reported AHI.

Short flow/evaluation periods may create denominator-related distortion of respiratory indices, while predominantly supine recordings and unavailable posture-stratified information may prevent reliable positional phenotyping. The identification of paradoxical lateral-worse respiratory patterns in several patients with elevated BMI further demonstrates that positional assumptions should be based on recorded physiological data rather than generalized expectations. In addition, marked discordance between snoring burden and AHI indicates that acoustic information should be regarded as supplementary rather than a direct measure of disease severity.

A structured review of technical recording adequacy, flow duration, oxygenation, positional information, and discordant physiological signals can improve the clinical interpretation of Level 3 HSAT. Patients with technically inadequate recordings, indeterminate positional findings, or persistent clinical suspicion despite an inconclusive HSAT should undergo appropriate repeat testing or attended polysomnography. Thus, the value of Level 3 HSAT lies not only in its accessibility but also in careful, clinically informed interpretation of the physiological information it provides.

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