

CLINICAL REVIEW

Home diagnosis of the obstructive sleep apnoea/hypopnoea syndrome

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polysomnography,
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Summary Polysomnography has been accepted by many as a “gold standard” for the diagnosis of the Obstructive Sleep Apnoea/Hypopnoea Syndrome (OSAHS). Although polysomnography is a good method for diagnosing OSAHS, there is no evidence that the results of polysomnography more accurately identify patients with the syndrome than more simple investigations which may be done at lower cost in the patient’s home. This article examines the evidence for and against home sleep studies and concludes that home sleep studies have a role. Precisely what that role is will depend on financial and organisational aspects for each sleep centre. © 2002 Elsevier Science Ltd. All rights reserved.

INTRODUCTION

Rapid increases in referral numbers have resulted in many sleep centres questioning the need to use relatively scarce sleep centre facilities to diagnose the Obstructive Sleep Apnoea/Hypopnoea Syndrome. Although home diagnosis can be used successfully in many patients, in-laboratory polysomnography remains the diagnostic method of choice in many countries either because of reimbursement policies or because of innate conservatism and reluctance to abandon a perceived “gold standard”. This article questions the value of such conservatism, but also attempts to identify the definite limitations of home sleep studies. In doing so I also ignore analyses which have found home sleep studies to be wanting in comparison to “gold standard” polysomnography [1,2] as the gold standard is at least tarnished if not made of fool’s gold. In addition, I will not address the

issues of reimbursement which, although real determinants of how much home studies are used, vary markedly throughout the world and are beyond the scope of this scientific review.

In 1994, the Standards of Practice Committee of the American Sleep Disorders Association [3] concluded that “*standard polysomnography is the accepted test for the diagnosis and determination of the severity and treatment of OSA*” and that unattended portable recording is an acceptable alternative only in patients believed to have severe OSA for whom “*standard polysomnography is not readily available*” or “*for patients unable to be studied in the sleep laboratory*”. This remains the accepted American policy but there has been no attempt to justify why polysomnography should be regarded as the “gold standard”.

The potential advantages to the patient of in-laboratory polysomnography are:

1. **Verification that the patient slept.** This is a real advantage in many situations, but it is extremely unusual for sleepy OSAHS patients not to sleep during an all night study. In one prospective study in patients with possible OSAHS [4], only 3% of patients

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slept less than 3 h and in no case did a repeat sleep study change the polysomnographic diagnosis.

2. **Determination of AHI.** The number of respiratory events/h of sleep – the apnoea + hypopnoea index (AHI) – has been regarded as the standard index of disease and disease severity. However, there is no evidence that the medical sequelae of OSAHS relate any more closely to AHI than they do to the number of respiratory events occurring in the whole night, the number of respiratory events/h in bed, oxygen saturation pattern [5–7] or indeed to non-respiratory variables, such as non-neurophysiological measurements of sleep fragmentation [8]. In reality, the best predictors of morbidity in individual patients, as assessed by improvements with CPAP therapy, are nocturnal oxygen saturation [7, 8] and movement during sleep [8], not AHI.

3. **Polysomnography allows alternative causes of sleepiness to be diagnosed.** The alternative diagnoses that could be made by polysomnography are principally:

- (a) *Narcolepsy.* Narcolepsy cannot be diagnosed on the basis of overnight polysomnography [9], although it may be necessary to perform a sufficiently robust overnight respiratory investigation to exclude the much more common OSAHS.
- (b) *Restless Leg Syndrome/Periodic Limb Movement Disorder.* Although periodic limb movements are well characterised by polysomnography, they are very common, occurring repetitively in 30% of those over 50 years old and in at least half of the elderly population [10]. It is difficult to conceive that PLMs causes sleepiness in all those affected. There is real doubt whether PLMs cause daytime sleepiness [11, 12] and a need for randomized controlled trials in this area [12, 13].

There is thus significant doubt whether polysomnography truly represents a gold standard. Indeed, the disparity of techniques and sensors used in polysomnography are clear indications that there is no such thing as a gold standard. The very inability of the American Academy of Sleep Medicine to publish the report of their expert task force on measurement techniques and diagnosing sleep apnoea as a Standards of Practice Recommendation [14] indicates the inherent conservatism in some quarters. In particular, continuing support for the role of thermal sensors in the detection of “hypopnoeas” is difficult to comprehend [40, 15]. Indeed, this lack of uniformity in polysomnography makes evaluation of studies using simplified monitoring very difficult as they are almost

invariably compared with the “gold standard” of polysomnography, yet the techniques and definitions used in polysomnography vary and may not be clearly specified.

HOME STUDIES

It is self evident that OSAHS can be diagnosed using home sleep studies, as any level of complexity of monitoring can be performed in the home setting, up to and including polysomnography [16, 17]. The advantages and disadvantages of performing diagnostic studies in the home are summarized below:

Advantages of home sleep studies

1. **Patients may sleep better** in the home, an environment with which they are familiar and in which the first night effect is minimised [18, 19].

2. **Patients may prefer** to be studied at home where they can regulate their own sleep times and have access to their home comforts. Shift workers particularly tend to find this an advantage. In our experience, the majority of patients will choose a home study over a laboratory study, if given a free choice, although the experience of other clinicians may be different.

3. **Sleep laboratory space.** The number of referrals to sleep centres and the number of sleep studies performed has risen exponentially in recent years [20]. For example, over the last 17 years in our sleep centre, the number of patients referred with possible OSAHS has risen from 25 per year to 1300 per year. It is thus physically difficult to fit this number of patients through sleep centres. More importantly, if the current epidemiological figures of a prevalence of around 2% [21] are correct, it is almost inconceivable that all such individuals could be channelled through overnight inpatient studies. Diagnosis on this scale can only be achieved either by extensive use of home sleep studies or by major capital investment in building additional sleep centres.

4. **Speed of diagnosis.** Patients may be diagnosed more rapidly if they do not have to wait for a sleep centre polysomnogram [22].

5. **Cost.** The capital cost of the hospital rooms used for sleep studies represents a significant percentage of the total costs of diagnosing OSAHS. In our centre, these capital costs represent 40% of the total diagnostic costs for polysomnography, and home

studies do not incur this cost element. This has been found to be a cost-effective approach [22–24].

Disadvantages of home sleep studies

1. **Sensor failure.** One of the major objections to home sleep studies is that in the unattended situation, sensor failure goes unnoticed and, therefore, a large number of sleep studies need to be repeated. In fact, the data substantiating this are poor and are also highly dependent on the experience of the staff involved, the complexity of the study performed and the degree of redundancy – and thus the existence of back-up sensors – used. If one examines the highest degree of complexity, namely home polysomnography, the data are variable. Portier [25] found in 103 patients that 20% of home polysomnograms yielded inadequate data in comparison to 5% of sleep laboratory recordings. In contrast, Fry *et al.* [16] lost none of 77 home polysomnographies due to technical failure. In over 7000 studies, the Sleep Heart Health Study had a failure rate of 5% for home polysomnography and the quality of the recordings improved with greater experience [26]. The major problems with signal quality, once adequate experience had been obtained, were with oximetry, EEG and EMG. Thus, home polysomnography is a possible option

Less complicated “limited sleep studies” which do not incorporate neurophysiological monitoring are potentially easier and cheaper to perform. Limited sleep studies usually still have a significant failure rate. However, using a simple SnoreSat system comprising an oximeter and sound recording, Issa and colleagues had no failures out of 129 studies [27]. With the NightWatch system, White and colleagues [28] had 3% of 70 studies in which inadequate data were obtained. Using the Edentec 3711 System (Mallinckrodt), we had an 18% failure rate in a study of 150 home investigations in which the patients applied the equipment to themselves at home [22]. This failure rate dropped to 5% once one of the electronic cards in the device was adequately stabilized.

Thus, failure rates for unattended home polysomnography are probably of the order of 5% in skilled hands and the failure rate for limited sleep studies is of the same order of magnitude. However, this figure probably depends on the robustness and complexity of the monitoring system used, the experience of the staff showing the patients how to use the equipment and whether staff or patients are applying the sensors and switching on the equipment.

2. **Sensor inadequacy.** Home sleep study equipment can range from the sophisticated and superb to the clearly inadequate. For example, some oximeters are much more accurate and freer from artefacts than others [29]. Similarly, some limited systems will use either thermal “flow” sensors or impedance chest movement sensors to detect hypopnoeas and neither are as accurate as inductance plethysmography or nasal pressure [14]. These differences will have a major impact on the accuracy of the results of the sleep studies performed.

3. **Fewer channels mean less information.** Inevitably, a limited sleep study with a reduced channel number will provide less information than polysomnography. This becomes particularly critical when a problem develops with one sensor or channel; in the sleep centre polysomnography situation, not only is there somebody present to rectify this, but there is usually a built-in redundancy of signals such that another channel will give back up information and the sleep study may still be readily interpretable even when channels “drop-out”. This is particularly an issue with very low numbers of channels, especially if sub-optimal sensors are used, as often the individual scoring the study tends to look at multiple channels before deciding whether an event has occurred.

4. **Technique of scoring.** There seems to be a greater – but poorly documented – tendency for sleep laboratories to use the automatic scoring software provided with limited sleep study equipment in contrast to polysomnography which most technicians score inter-actively. The software for limited sleep study interpretation has largely not been validated by independent experts.

5. **Lower CPAP use.** It has been suggested that patients who are diagnosed by limited sleep study techniques have lower subsequent CPAP use [30]. I can see no rational reason for this observation and, furthermore, in our prospective control study, there was similar CPAP usage in patients diagnosed by limited sleep studies carried out at home in comparison to carefully matched control patients [22]. CPAP usage is largely determined by the patient’s symptoms and OSAHS severity [31] and the education and support provided [32].

There is, therefore, adequate data to justify the use of home sleep studies for the diagnosis of OSAHS. The areas of difficulty remaining include:

- (a) Which sensors should be used?
- (b) Should the patients or technicians set up the equipment?

- (c) What result should be taken as diagnostic?
- (d) Should all patients have home sleep studies?
- (e) What happens if the study is negative?
- (f) What happens if the patient diagnosed on a home study does not respond to treatment for OSAHS?

(a) Which sensors should be used? The choice of sensors to be used is open to considerable debate. The simpler the system, the cheaper and often the easier to use.

For these reasons, considerable attention has been paid to the use of “oximetry alone” studies to diagnose OSAHS, and widely divergent conclusions reached [4, 33–38]. A possible explanation is that those studies which defined hypopnoeas as requiring coincident desaturation, perhaps not surprisingly found that oximetry alone studies were useful [33, 37, 38], whereas those that could diagnose hypopnoeas in the absence of desaturation found that around one-third of cases of OSAHS were missed by oximetry alone [4, 35]. As the current definition of a hypopnoea does not require desaturation [14], oximetry alone may be less accurate as a diagnostic test than some have reported.

There is no doubt that a trained observer can confidently diagnose OSAHS from positive oximetry traces [4, 33] but the problem is that false negatives are common and a normal oximetry trace does not exclude severe OSAHS which will respond well to treatment. Indeed, younger and thinner OSAHS patients often do not desaturate despite frequent apnoeas and hypopnoeas and it is highly undesirable to fail to diagnose such patients. It may be possible to derive indices computed from oximetry traces which contribute usefully to the diagnosis of OSAHS [34, 35, 38] but these would seem to be best used in conjunction with other respiratory variables.

The conservative approach would be to use the sensors needed to allow OSAHS, as currently defined [14], to be diagnosed. Thus, the system should include:

1. **Detectors for apnoeas** – nasal pressure [39] and/or thermal sensors.
2. **Detectors for hypopnoeas** – thoracoabdominal movement by uncalibrated [14] inductance plethysmography [40] or nasal pressure [39].
3. **Oximetry.**

These two or three channels should allow an adequate estimation of the number of significant respiratory events/h recorded. These channels are used in a number of commercially available systems including the AutoSet and Embletta (ResMed, San Diego,

CA, USA) [41–46] and the Stardust (Res-pironics, Pittsburgh, PA, USA).

More radical solutions incorporate novel sensors which may indirectly detect respiratory events – and arousal – by measuring a marker of beat to beat blood pressure. Such devices may measure pulse transit time [47–49] or peripheral arterial tonometry [50, 51]. The use of these techniques hold promise but require further rigorous testing before their role can be established.

Another different approach is to use a static charged mattress system [52, 53] which may give measures of breathing pattern and sleep state [54]. Evaluation in the home setting is needed.

Other sensors which can be incorporated include:

1. **Snoring** – detected by microphones [27] or oscillation in nasal pressure, can be useful to confirm airway obstruction.
2. **Sleep duration** – non-invasive markers of sleep time could perhaps be obtained from movement detection by actimetry or video. These techniques need rigorous assessment.
3. **Arousals** – Scoring arousals automatically from video images provides clinically useful information at least in the sleep centre [8], although this has not been tested in the home. The pulse transit time and peripheral arterial tonometry methods require further study. Other non-neurological ways of detecting arousals also need investigated further, including the co-incident increase in ventilation [45] or body movement [8]. I firmly believe that OSAHS should be renamed the “respiratory arousal syndrome” and that diagnostic efforts should be centred on detecting by simple techniques arousals that occur in conjunction with respiratory changes. It must be remembered that the value of arousal scoring from polysomnography has never been established, the normal range is wide [55] and the reproducibility between centres poor [56].
4. **Body position** – this can be readily measured in the home from piezo-electric or mercury tilt switches.
5. **Leg movements** – again these can be readily recorded in the home if desired either from piezo-electric sensors or EMG electrodes.

(b) Should the patients or technicians set up the equipment? This decision will depend on local economics and the complexity of the equipment used. Clearly, it is more expensive if a technician has to visit

the patient's home and so the usual choice is between the equipment being attached to the patient in the sleep centre and then going home or the patient attaching the equipment at home. We find patients prefer the latter in our area but both approaches have similar costs. The relative failure rates of these approaches have not been assessed.

(c) What result should be taken as diagnostic?

There is no clear answer to this as there is no clear threshold of AHI above which patients will benefit from treatment. Limited sleep studies will yield information on events per hour in bed. This clearly is not the same as the number of events/h slept [4] and there is no possible conversion formula. It would seem sensible to have a slightly higher threshold for confident diagnosis of OSAHS if there is no knowledge of sleep quality as some respiratory events may occur in wakefulness and would normally be ignored [45]. We have thus adopted a conservative approach of at least 20 events/h recorded on a limited sleep study with appropriate sensors and manual scoring being diagnostic of OSAHS in symptomatic patients [46]. In patients towards the lower end of this range, if an inadequate response to therapy is obtained, the diagnosis should be questioned and a more detailed test involving sleep monitoring considered. In our experience, this is rarely needed but protocols must build in this option.

(d) Should all patients have home sleep studies? No. Patients for whom home studies are not the first choice include those travelling from a distance and those mentally or physically unable to perform the test. Beyond these, which patients require a home study will depend on local situations and the techniques used to perform CPAP titration. There is now reasonable evidence that split night studies can result in adequate CPAP titration and long-term outcomes, at least in the more severe patients [59–61]. Clearly, performing a home diagnostic test will not save any sleep centre nights if split night studies are the local norm. However, if home CPAP titration proves to be as effective as sleep centre titration [23, 62, 63] then the savings with home diagnosis become large again.

(e) What happens if the study is negative?

Patients who are sleepy but have 20 events/h on a good home study require further evaluation to clarify the cause of the sleepiness. This is an important safety net. At present this will usually take the form of polysomnography, but sometimes tests of objective sleepiness such as the MSLT [57] or MWT [58] may be more appropriate.

(f) What happens if the patient diagnosed on a home study does not respond to treatment for OSAHS? Any patients who are diagnosed with OSAHS on a home study but who remains sleepy, despite adequate use of CPAP should also be further investigated in case another sleep disorder is missed. With these provisos, I believe that home sleep studies can serve a useful role, not only in diagnosing OSAHS more cheaply, but also in speeding up the diagnostic process [22].

CONCLUSION

There is clear evidence that home studies can be used to diagnose OSAHS and that they can represent a cost-effective option.

Practice Points

1. Home sleep studies can save time and money.
2. With many systems, the patients can apply the equipment themselves.
3. At present, most systems require to be scored manually.

Research Agenda

1. Further prospective studies into the relative values of polysomnography and home diagnosis.
2. Correlational studies between sleep study variables and outcome.
3. Investigations into the utility of diagnosing arousals either neurophysiologically or by cardiovascular or respiratory recording.

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GLOSSARY OF TERMS

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| MWT | Maintenance of Wakefulness Test |
| MSLT | Multiple Sleep Latency Test |
| OSAHS | Obstructive Sleep Apnoea/Hypopnoea Syndrome |
| PLM | Periodic Limb Movements |