Simplifying the Complexity of Polysomnography - Understanding the Objective Measurement of a Sleep Disorder

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Scope

- Subjective Measures of Sleepiness
- Physiologic/Biologic Measures of Sleepiness
- Polysomnography (PSG)
  - Sleep Unit based and Portable (Home) PSG in 2010
  - Diagnostic PSG
  - Continuous Positive Airway Pressure (CPAP) titration PSG
  - Multiple Sleep Latency Test PSG

Sleepiness and Fatigue

Although these terms are used interchangeably there are differences. Sleepiness refers to the urge to fall asleep. It is the result of a biological need to sleep that can be irresistible. Fatigue refers to the reluctance to continue a task as a result of physical or mental exertion or a prolonged period of performing the same task.

The Problem - Sleepiness and Fatigue

A substantial body of research demonstrates that sleepiness and fatigue result in:

• Slower reaction time.
• Reduced vigilance (delayed responding, longer periods of non-response to stimuli).
• Deficits in the speed and accuracy with which information is processed.
• Diminished ability to plan ahead.
• Behaviour becomes increasingly reactive as opposed to proactive.

Shiftworkers, especially night and rotating shift workers, often suffer from poor quality of sleep as well as inadequate quantity of sleep. The effects of sleep loss accumulate over time and do not dissipate. For a driver or machine operator the main effect is a progressive withdrawal of attention from the road, or work demands, leading to impaired performance behind the wheel in the case of sleepy drivers, or with equipment for the machine operator. The ultimate impairment is falling asleep at the wheel or while using machinery.

There are now substantial data that the disorder Obstructive Sleep Apnoea is associated with an increased risk of crashes in drivers of passenger cars (Sassani et al. 2004; Tregear et al. 2007).

Even sleeping 30 or 40 minutes less than needed each night during a normal work week can result in a 3 to 4 hour sleep debt by the weekend, enough to significantly increase levels of daytime sleepiness. Growing evidence shows that a chronic lack of sleep increases the risk for developing obesity, diabetes, cardiovascular disease, and infections.

Obstructive sleep apnoea affects approximately 25% of middle-aged men in Australia. Less common, but equally serious, is narcolepsy, a condition in which a person falls asleep without warning during the daytime. It is believed that less than a quarter of people with narcolepsy are ever diagnosed.
The Australian mining community is susceptible to exhibiting a high prevalence of sleep disordered breathing given the dominance of male workers and reported body mass index (BMI) averages.

In a recent NSW mining study, the mean BMI for the total mining population of NSW Coal Miners was found to be 28.22, which is overweight. A total of 76.8% of the miners in the health data collected for that study were either overweight (46.4%) or obese (30.4%). This is a concern regarding the health issues associated with both being overweight and ageing. Being overweight or obese substantially raises the risk of illness from high blood pressure, high cholesterol, type 2 diabetes, heart disease and stroke, gallbladder disease, arthritis, sleep disturbances and problems breathing, and certain types of cancers. The Australian Institute of Health and Welfare statistics show that 67% of adult men and 52% of women were overweight or obese in 2000. NSW coal miners (at 76.8%) are considerably higher.

Site Fatigue Management Training

Fatigue Calculators and Questionnaires -Subjective Measures of Sleepiness

- Improve level of knowledge and awareness.
- May prompt individual action.
- Subjective tools. Rely on personal honesty/integrity of the individual to use them or act on them.
- Fatigue calculators may provide false sense of security.

Physiologic Measures – Signs of Sleepiness

Optalert Glasses (1992-)

Optalert's patented technology continuously measures drowsiness by using invisible pulses of light to detect eye and eyelid movement. Tiny light emitters and receivers are built into the frames of Optalert glasses worn by the driver. The glasses are connected to the Optalert Vehicle System, installed within the vehicle, which processes all the information being transmitted from the glasses. Whenever Optalert detects the onset of drowsiness – usually before the driver becomes aware of it – a loud beeping noise and a voice message warns the driver immediately.

Smart Cap (2009)

SmartCap technology - fatigue information is collected by microelectronics concealed within a baseball cap. The technology uses a number of sensors to measure brain-wave information through hair. It then applies an independently-validated formula to identify when the wearer is experiencing symptoms of fatigue. "When a fatigue danger limit is reached, a warning message is sent from the operator's cap to an in-cab display, notifying operators of the threat, and alerting them to the need to stop, rest and refresh," (*Mining Daily,* 1 October 2009).

Physiologic Measures

- Objective measure of signs of sleepiness if interpreting features correctly.
- Provides potential opportunity for evasive action to me taken – potentially mitigating a real time accident.
- Will not permit specification or quantification of a sleep disorder beyond identifying a very high propensity for sleep in a given individual.

Polysomnography or PSG or Sleep Study

Objective Measure of Sleepiness, Sleep Quality and Sleep Quantity performed in a sleep unit or at home/in a mine site donger with a portable PSG unit. PSG will provide data suitable for the medical diagnosis of a sleep disorder. A PSG is the continuous and simultaneous recording of multiple physiologic variables during sleep, that is, electroencephalogram (EEG), electrooculogram (EOG), electromyogram (EMG), electrocardiogram (ECG), respiratory air flow, respiratory movements, leg movements and other electrophysiologic variables.

The name is derived from Greek and Latin roots: ‘poli' (many), 'somnus' (sleep), and 'grapho' (to write).

Evolution of Polysomnography

- 1930 Berger sleep vs. waking Electroencephlogram (EEG)
- 1937 Loomis EEG of different sleep states
- 1953 Aserinsky and Kleitman Electro-oculogram (EOG)
- 1957 Dement & Kleitman describe Rapid Eye Movement (REM) sleep
- 1959 Jouvet & Michel Electromyogram (EMG) decrease in REM sleep
- 1968 A manual of standardised terminology, techniques and scoring system for sleep stages of human subjects by Allan Rechtschaffen and Anthony Kales

- 1978, 1980 McGregor, Weitzman, Pollack PSG to include oximetry, respiratory effort & airflow.
- 1981 Colin Sullivan developed Continuous Positive Airway Pressure treatment for Obstructive Sleep Apnoea
- 1992 ASDA (American Sleep Disorders Association) EEG Arousals: Scoring rules and examples
- 1999 Sleep-related breathing disorders in Adults: Recommendations for Syndrome Definition and Measurement Techniques in Clinical Research - Report of an American Academy of Sleep Medicine Task Force (*Sleep* Vol 22 No. 5)

Sleep Study Referral Process

Sleepy individual – Discusses their sleep problem with General Practitioner or Sleep Specialist.

If Dr agrees there is need for a sleep study – he or she completes the referral and faxes or emails it for booking with the sleep service.

Polysomnographic Tests

- **Diagnostic PSG** - investigative study to determine if there are identifiable problems with the patient's sleep.
- **CPAP titration PSG** - If a patient is identified as having obstructive sleep apnoea, a PSG is performed in which the nurse or technician adjusts the CPAP pressure level during the study.
- **Split Night PSG-** Combines a diagnostic study and a CPAP titration study into one night. The patient is diagnosed during the first half of the night; CPAP applied the second half if required by protocol.
- **Multiple Sleep Latency Test** (MSLT)
- **Maintenance of Wakefulness Test** (MWT)

Both MSLT and MWTs are daytime tests.

88 Sleep Disorders listed in the International Classification of Sleep Disorders Diagnostic and Coding Manual (2001)
http://www.esst.org/adds/ICSD.pdf

We most commonly find……

- Obstructive Sleep Apnoea
- Insomnia
- Narcolepsy
- Depression
- Periodic Limb Movements in sleep
- Withdrawal from stimulants
- Insufficient sleep syndrome
- Drug Dependence/Abuse
- Medication side effects
- Post Traumatic Hypersomnia

- Obesity Hypoventilation
- Respiratory Failure
- Patients with Night Terrors, REM Behaviour Disorders and Epilepsy

Physiological measurements undertaken during Polysomnography

Sleep

- EEG (brain signals)
  - C4 – A1, C3 – A2
  - O2 – A1, O1 – A2
- EOG (eye muscle activity)
  - LOC (left eye) and ROC (right eye)
- EMG (chin muscle activity)
  - EMG s (chin = sub-mental)

Respiration

- Airflow (Oral -Thermistor, Nasal pressure - Cannula)
- Respiratory Effort
  - Thorax (Ribcage)
  - Abdomen (Diaphragm)
- Pulse Oximetry
  - SaO_2 (Oxygen saturation)
  - Pulse
- Body position
- Transcutaneous CO_2 (when requested)
- Microphone (snoring)

Muscle Activity

- EMG leg EMG t (anterior tibialis muscle – along shin)

Cardiac status

- ECG

Setting up for the Sleep Study Head Measurement - 10-20 System EEG electrode placement landmarks.

Setting up for the Sleep Study - Site preparation and glue-on Electrode Application.

Setting up for the Sleep Study - Application of 'Respi-Bands', Leg electrodes and Nasal Cannula.

Setting up for the Sleep Study - Connection of Patient to 'Headbox'.

The Diagnostic Sleep Study -Overnight attended monitoring of the patient and data signals

Sleep Unit PSG or Portable PSG?

Sleep Unit based PSG

- Performed for over 30 years.

- Considered ‘gold standard’. Usually conducted within a hospital sleep unit or sleep clinic.
- Patient is ‘attended’ overnight by a Scientist, Nurse or Medical staff.
- Patient well being and signal quality/data integrity is monitored and maintained.
- PSG hardware capable of 27+ channels for data capture.
- Video monitoring.
- Pressure titration of CPAP or Bilevel machines can be performed by a scientist, nurse or medical staff.

Portable (home based) PSG

- Performed for approximately 12 years in Australia.
- Usually conducted in the patient’s home after evening clinic ‘set-up’. Reduced cost.
- Non-attended.
- Potential for data loss if lead/s dislodged.
- Usually no video monitoring.
- 2007 - portable PSG hardware invented capable of measuring majority of sleep unit based channels.
- Some sleep service providers, chemists and other outlets still using single or double channel monitoring devices – NOT PSG -risk of false positives, false negatives sleep study results.
- Medicare Australia intervention 2008 - 2010

Regulation and Best Practice Guidelines Portable PSG
Medicare Schedule Advisory Committee (MSAC) findings March 2010

After considering the strength of the available evidence in relation to safety, effectiveness and cost-effectiveness, MSAC supports public funding for the use of Level 2 unattended sleep studies for investigation of obstructive sleep apnoea (OSA) for a duration of at least 8 hours, for an adult aged 18 years and over, where:

(a) the patient is referred for the investigation by a medical practitioner who has formed a reasonable clinical view that the patient has a high probability of having OSA

*[(b) the necessity for the investigation is determined by a qualified sleep medicine practitioner (as defined in the explanatory notes to the MBS) prior to the investigation;] [*referred study]

(c) a qualified sleep medicine practitioner has:

(i) established quality assurance procedures for the data acquisition; and
(ii) personally analysed the data and written the report;

(d) during a period of sleep, the investigation is a recording of a minimum of seven channels which must include continuous EEG, continuous ECG, airflow, thoraco-abdominal movement , oxygen saturation; and two or more of EOG, chin EMG and body position.

(e) interpretation and report of the investigation (with analysis of sleep stage, arousals, respiratory events and assessment of clinically significant alterations in heart rate) are provided by a qualified sleep medicine practitioner based on reviewing the parameters recorded under (d) above.

MSAC supports the payment of the benefit only once in a 12-month period, and recommends review of the Schedule Fee for Level 2 unattended studies in the current interim Medicare Benefits Schedule item 12250 to ensure that the service remains cost-effective.

MSAC does not support public funding for Level 3 or 4 unattended sleep studies.

MSAC does not support public funding for any unattended sleep studies for diagnosis in a paediatric setting or for reassessment of treatment efficacy.

http://www.msac.gov.au/internet/msac/publishing.nsf/Content/app1130-1

http://www.health.gov.au/internet/msac/publishing.nsf/Content/2AD0E9BD12315EB9CA2575C5002872A9/$File/1130_MSAC_Report.pdf

Regulation and Best Practice Guidelines
American Academy of Sleep Medicine Clinical Guidelines for the use of unattended portable monitors 2007

http://www.ncbi.nlm.nih.gov/pubmed/18198809

1.2.1. Portable Monitoring (PM) is not appropriate for the diagnosis of OSA in patients with significant comorbid medical conditions that may degrade the accuracy of PM, including, but not limited to, moderate to severe pulmonary disease, neuromuscular disease, or congestive heart failure.

1.2.2. PM is not appropriate for the diagnostic evaluation of OSA in patients suspected of having other sleep disorders, including central sleep apnea, periodic limb movement disorder (PLMD), insomnia, parasomnias, circadian rhythm disorders, or narcolepsy.

Objective Testing – Our Service – Portable Sleep Study performed with Compumedics Somte PSG device

Meets Medicare Australia (2008-2010) guidelines
Meets AASM (2007) guidelines as a Level 2 device.
14 – 27 channels including multiple EEG for precise sleep staging by scientist.
Clinically robust data capture.

PSG Analysis

Study data is scored by a qualified Sleep Scientist and reported by Sleep Physician

Diagnostic Sleep Study Signals

Awake - eyes closed EEG Alpha waves – 8-13Hz EOG Reflects EEG EMG highest level of recording	Awake - eyes open EEG small amplitude, mixed frequency EOG blinks EMG highest level of recording
Stage 1 Sleep EEG: Slower activity than wake, can see each distinct wave. EOG: Rolling eye movements, sinusoidal waves in opposing directions EMG: Slightly reduced from wake	Stage 2 Sleep EEG: Presence of spindles or K-complexes EOG: No movements but may reflect EEG activity EMG: Slightly reduced
Stage 3 Sleep EEG: 20-50% of the epoch has waves 75µV in amplitude, of frequency less than 4 cycles per second. EOG: No movement. May reflect EEG waves. EMG: Slightly reduced.	Stage 4 Sleep EEG: more than 50% of the epoch has waves 75µV in amplitude, of frequency less than 4 cycles per second EOG: No movement. May reflect EEG waves. EMG: Slightly reduced.
REM Sleep EEG: small amplitude, mixed frequency. May have sawtooth waves. Resembles awake with eyes open. EOG: rapid eye movements in opposing directions. EMG: reduced to lowest level of recording.	

Normal Sleep Architecture

- Normal sleep cycle:

Stage 1	4%
Stage 2	38%
Stage 3	4%
Stage 4	16%
REM	16%

(Mathur and Douglas, 1995)

Bruxism - Rhythmic muscle activity, reflected in EEG/EOG channels

REM Behaviour Disorder - Increased EMG, reflected in EEG/EOG

Obstructive Sleep Apnoea
Snoring
Hypopnoea
Apnoea

Effects of Obstructive Sleep Apnoea

Hypertension
Coronary artery disease
Congestive heart failure
Transient Ischaemic Attacks/
Cerebrovascular Accidents
Atrial Fibrillation
Type 2 Diabetes/ Insulin resistance

Severity of Obstructive Sleep Apnoea

Total number of complete cessations (apnoea) and partial obstructions (hypopnoeas) of breathing occurring per hour of sleep. These pauses in breathing must last for 10 seconds and are associated with a decrease in oxygenation of the blood.

Respiratory Disturbance Index (RDI)	<5 /hr Normal
	5-14 /hr Mild
	15-30 /hr Moderate
	> 30 /hr Severe

Severe patients can obstruct over 150 times per hour (over 1000 times per night).

The Sleep Report – Normal Study and Obstructive Sleep Apnoea

CPAP – Continuous Positive Airway Pressure

- Considered Gold Standard treatment for Obstructive Sleep Apnoea.
- Air passes through a mask into the patient's nose and/or mouth, and into the throat, where the slight pressure acts as a splint to keep the patient's airway open and prevent obstruction.

CPAP – Continuous Positive Airway Pressure Titration PSG

CPAP pressure titration PSG: Entire night summary

Effects of OSA and CPAP - Marin et al, Lancet 2005

Daytime PSG – Multiple Sleep Latency Test (MSLT)

- Measures the rapidity of the patient falling asleep
- Conducted the day after a Diagnostic Study
- Subject while lying down is asked to sleep (20 minutes)
- If the patient falls asleep in 20 minutes, he is given another 15 minutes to get into REM stage
- Measures Sleep Latency (time taken to fall asleep) Measure REM Latency
- Important in the diagnosis and confirmation of Narcolepsy
- Repeated 5 times every 2 hours throughout the day

MEAN SLEEP LATENCY	REM ONSETS (in 5 naps)
10-15 min MILD	0-1 NORMAL
5-10 min MODERATE	≥ 2 ABNORMAL
< 5 min SEVERE	

Diagnosis of Narcolepsy = mean sleep latency < 8 mins with 2 or more REM periods in any of the naps.

Conclusion

- Polysomnography (PSG) can be viewed as an important adjunct to existing fatigue management training and subjective and other physiologic measures of sleepiness.
- PSG is an objective measure of sleepiness, sleep quality and sleep quantity in addition to other variables.
- PSG permits the medical diagnosis of an underlying sleep disorder.
- Not all Portable (Home) sleep study devices and sleep services in Australia meet current Medicare guidelines.
- Not all sleep services will provide local access to a Sleep Physician for consultation.
- Not all sleep services will be able to perform all of these tests.
- Some sleep disorders require regular and ongoing treatment management. Not all sleep services will provide ongoing support in a fixed location for patients commencing treatment.

The onus is on each organisation to locate a sleep service that can meet the above criteria and provide polysomnographic testing and treatment pathways suitable to the needs of the workers of their organisation.

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