Current topic

Polygraphic studies

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Polygraphic recordings, simultaneous recordings of different physiological signals, have been used by physiologists for over 80 years, but their use in clinical medicine is more recent. This is partly due to the development of smaller, mobile, sophisticated recording equipment that is easy to use and supplies a great deal of information. The machines are, however, costly, time consuming, and produce more data on physiological variables than it is possible to analyse. I shall, therefore, review some of the clinical applications of polygraphic recordings and the problems likely to be encountered when they are used.

A polygraphic study is the simultaneous recording of two or more physiological variables over a period of time. These may be long (12–24 hours) if a changing pattern is being analysed during different activities, or sleep, or they may be short when a single event is being studied—for example, prolonged apnoea or bradycardia, or both, and their association with gastroesophageal reflux. All recordings are put on paper, magnetic tape, or both depending on the type of analysis used.

Methods

Ideally, the study should be performed in an environment controlled for light, temperature, and sound that is free from electrical interference. Often, however, this is not possible and the recording has to be done in a busy ward.

Measurements of respiratory function. Respiration is usually recorded indirectly by impedance (intensive care monitors), abdominal and thoracic movement (strain gauges), or inductance plethysmography (Respirace). These methods have limitations in that movement of the body interferes with the quality of the signal and obstructive apnoea cannot be diagnosed as it requires simultaneous measurement of air flow through the nares. This can be achieved by measuring either the temperature difference (thermistor) or CO₂ difference (capnograph) between the inspired and expired gas.

Central apnoea (loss of respiratory drive) is defined as no air flow for 10 seconds or longer, with no associated ventilatory movements of the chest or abdomen. Obstructive apnoea occurs when there is no air flow but continued chest and abdominal ventilatory movements. Quantitative measurements of gas flow are usually made with a pneumotachometer, which is attached to a mask applied firmly to the face or nares. The tactile stimulation of an infant's face, however, alters respiratory patterns and therefore limits the use of the mask.¹ A quantitative measurement can be made without a face mask using the barometric plethysmograph.² This is accurate and reliable but is complex and expensive to install, and its use is limited to a few research centres.

Measurements of oxygen concentration. Arterial oxygen concentrations are usually measured as saturation by a pulse oximeter. The advantages over transcutaneous oxygen tension measurements are the rapid response time, ease of calibration, and ease of use; the electrode has no membrane to damage and can remain attached to the limb or ear for long periods.

Measurements of cardiovascular function. The electrocardiogram (ECG) is recorded with the standard four lead system. The two chest leads may also be used for the impedance respiratory monitor.

Measurements of central nervous system functions. The electroencephalogram (EEG) is used to define sleep states using a three electrode or multielectrode system following the 10/20 configuration. If there is a possibility of seizures, the continuous EEG is sometimes combined with video monitoring.

Measurements of musculoskeletal function. In many sleep study laboratories surface electromyograms (EMG) recorded from extra-ocular muscles are used to define rapid eye movement sleep. Additional information about the respiratory system is sometimes obtained using surface EMGs from intercostal

muscles to measure chest wall distortion, and from the diaphragm to estimate muscle fatigue.

Oesophageal pH. An indwelling oesophageal electrode giving a continuous reading is used to detect acid regurgitation into the lower oesophagus, which is an index of gastroesophageal reflux.

Measurement of sleep states. In normal infants and children, patterns of breathing and heart rate vary in different sleep states. In quiet sleep (non-rapid eye movement) the breathing pattern is regular with little variability, while in active sleep (rapid eye movement) variability is wide and apnoea common.³ The definitions of states are, therefore, important in the interpretation of respiratory and cardiac patterns. To define sleep states most laboratories use a combination of behavioural signs—for example, body movement, facial and eye movements, vocal sounds, and EEG readings.^{4 5} Unfortunately no one system is accepted by everybody, making comparison of results among laboratories difficult.

Data analysis

Analysis of a 12 hour recording is often difficult as there may be over 400 pages of data. Sometimes analysis consists of flipping through the pages and picking out any abnormal sections for further analysis. Computer analysis requires a magnetic tape record and its success depends on the quality of the signal, the questions asked, and the program used. Electrocardiographic signals are best interpreted by recording heart beat intervals in milliseconds and measuring median beat intervals and their interquartile range for long term variability and differences in successive beat intervals for short term variability. Bradycardias are easily isolated and can be edited separately. Respiratory signals are more difficult to analyse as they are particularly sensitive to body movement, and baseline shift is common. Analysis usually entails measuring breath to breath intervals (breathing rate) and their variability. Data may be obtained in different sleep states on the occurrence (%) of bradycardia, central apnoea, and its duration. This information is important for defining normality at different ages when defects in maturation are postulated.

Analysis of life threatening events is still best done by hand. In long recordings this is only possible using magnetic tape records, from which events may be abstracted and written out separately. Because tapes may be edited, and replayed over and over again for reanalysis as new theories emerge, they are invaluable in polygraphic studies. When

two physiological variables are compared the response time of the recording instruments must be known as, for example, some transcutaneous oxygen instruments have a delay of 12 seconds or more.

The person analysing the record must be able to say what the readings mean, and whether they lie within the normal range, which may be difficult.

Clinical applications

Screening for sudden infant death syndrome. Despite a lot of research, sudden infant death syndrome cannot be predicted or excluded by polygraphic studies.^{6 7} Suspected risk factors such as apnoea and periodic breathing are seen in normal subjects,^{8 9} as are extrasystoles, bradycardias, sinus pauses, and nodal rhythms.^{10 11} It is this new information about the wide range of normality that polygraphic studies have contributed to clinical medicine. As one clinician quoted in a recent review about ambulatory ECG said: 'a normal person may be defined as someone who has not been adequately investigated'.¹⁰ The wide range of normality has made the isolation of true abnormality difficult; in some patients loss of variation indicates abnormality, for example infants with severe congenital malformations of the lung.¹² In others, the variation may occur too frequently, inappropriately, or be prolonged. It is in this group that there is the greatest difficulty in defining true abnormality, and in the past the wrong diagnosis may have been made if age matched controls were not studied as well. For example, in some healthy full term infants sustained episodes of periodic breathing are rare in the first week, become common between two and four months, and decrease thereafter.⁸

The investigation of life threatening events. Many studies have shown that polygraphic recordings may help in the diagnosis and management of recurrent life threatening events.¹³ Ideally the event occurs while the recordings are being made. In practice this is unlikely to happen because of the random occurrence of the events, and the vagaries of electronic equipment. Events usually affect the respiratory, cardiac, or central nervous systems. The recording at the time of an event should confirm whether an event has occurred and, whether one or more system was affected; it should also indicate which system was most seriously affected and the possible factors causing the event.

Of all respiratory events, prolonged central apnoea during quiet sleep is the easiest to diagnose, as body movement is absent and a good quality

recording can be made. Obstructive apnoea, either in isolation or combined with central apnoea, is more difficult because it is usually associated with body movement, which causes interference to the respiratory signal; in addition, two simultaneous recordings are needed. Obstructive apnoea is often associated with obvious bradycardia, continued ventilatory effort,¹⁴ and a drop in oxygen saturation. The obstruction may be due to an abnormality of the oropharynx, or it may be secondary to gastroesophageal reflux. Abnormality of the oropharynx may be easy to diagnose as in the Pierre Robin syndrome, where the cleft in the soft palate, small jaw, and posteriorly placed tongue leads to obstruction of the laryngeal inlet. Enlarged tonsils, adenoids, and uvula can also obstruct breathing, but it is only from studies of follow up data after surgery that the problem may be put into perspective.^{15,16}

The assessment of the role of gastroesophageal reflux is just as difficult. Acid regurgitation will be recorded by the oesophageal pH monitor, and it can be correlated with the apnoea provided that all signals are recorded on the same record or that they share a common time base. The difficulty lies in their interpretation. Gastroesophageal reflux seems to occur with body movement when the infant is awake¹⁷ or in active sleep,¹⁸ a time when apnoea is common. Analysis of the timing of reflux and apnoea suggests that most episodes of prolonged apnoea are not accompanied by reflux¹⁹ and that the events are not necessarily associated.²⁰ This conclusion has been challenged, and it seems likely that a few infants present with obstructive apnoea caused by gastroesophageal reflux when awake.²¹

If the life threatening events are caused by recurrent abnormalities in cardiac rhythm these should be obvious on the ECG tracing as it is not grossly affected by body movement. Accurate diagnosis depends on an ECG tracing before, during, and after the event, so that all the components of the ECG may be analysed. If the period of study is prolonged a magnetic tape record is necessary for this type of analysis.

Polygraphic studies and epilepsy. Epilepsy alone can be difficult to diagnose, as loss of consciousness may be caused by a cardiac arrhythmia rather than a cerebral lesion.²² Conversely, partial seizures in newborn babies may be accompanied by apnoea and bradycardia.²³

Considerable improvements have been made in the accuracy of diagnosis by simultaneous EEG recording and video monitoring.²⁴ The advantage of the technique is that the event can be repeatedly reviewed, and carefully defined, both in terms of the

child's behaviour and serial EEG recordings. This objective technique has helped in the diagnosis of different types of epilepsy, their localisation, quantification, and response to drug treatment.²⁵

The technique may also be of value in diagnosing neonatal seizures. This diagnosis is still largely based on clinical observations without reference to EEG tracings.²⁶ In 1983 Eyre *et al*²⁷ reported a technique for the rapid analysis of EEG tracings to diagnose neonatal seizures. Unfortunately tonic seizures are not always accompanied by EEG abnormalities; in a study of 400 tonic seizures in 120 babies, 102 episodes had no accompanying seizure activity on EEG.²⁸ The concept that so called tonic seizures in newborn babies are due to epileptic discharges in the brain needs to be re-examined. The opposite may also be true, in that some EEG seizures are not accompanied by abnormal behaviour; one series reported a figure of 79% of 393 electrographic seizures analysed.²⁹ As this technique becomes more available, our clinical definition of epilepsy will become more sensitive and our treatment more appropriate. In the newborn period this is particularly important because of the strong association between seizures and permanent handicap.³⁰

Summary

Polygraphic recordings have provided new information about the wide ranges of normality in various diseases and the process of maturation from birth to childhood. New techniques will help to document clinical events accurately, improve diagnosis, and evaluate treatment.

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