AMBULATORY RECORDING OF PHYSIOLOGICAL PARAMETERS IN SPINAL CORD INJURED PATIENTS DURING ACTIVITY.

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Abstract

An investigation has been undertaken using a portable monitoring system to record the physiological parameters of patients with spinal cord injuries (SCI) during a period of prolonged activity.

During the rehabilitation phase of SCI patient recovery, the progressive change in physiology has usually been studied in an intensive care unit (or ward) bedside situation. It is of considerable clinical interest to monitor the physiology parameters of SCI patients over a prolonged interval of time, and during a variety of activities so that the effect of these parameters can be examined in an ambulatory setting.

The monitoring system used in this study consisted of a computer (desktop/laptop), sensors, proprietary software and a data logger. The 32-channel portable data logger, the Siesta (Compumedics, Melbourne, Australia), being small and light provided a convenient ambulatory monitoring capability. The unit’s memory card provided over 12 hours of ambulatory monitoring without the need for umbilical leads or a telemetry link.

The study determined that ECG, upper limb EMG, respiration, pulse oximetry, and muscle spasms (acceleration) can be readily measured with the existing sensors provided by Compumedics. Initial results suggest that the sensors must be stabilised to ensure continuous monitoring and some movement artifacts are required to be dealt with.

Keywords: Ambulatory monitoring, autonomic nervous system, data logger, physiological monitoring, spinal cord injury.

Introduction

Spinal cord lesions result in a variety of abnormalities effecting the cardiovascular, thermoregulatory, gastrointestinal, urinary and reproductive systems [1]. Following a spinal lesion, patients go through stages of ‘spinal shock’, spinal cord depression, and then a later stage when isolated activity of the spinal cord usually returns. These progressive changes are of clinical interest, and during the rehabilitation of SCI patients such changes take place in the context of a program of prescribed activity. It is in this context that the current project is being undertaken to measure a range of physiological parameters in SCI patient over a prolonged period of daily activity.

Methods

Ambulatory technology

The monitoring equipment is the Siesta 32-channel digital data logger (Compumedics, Melbourne, Australia).

Figure 1: Siesta (front view).

Figure 2: Siesta with back removed.
This system has been developed for sleep research studies and comes with a range of sensors for that purpose. The system's general characteristics are [2]:

- **Weight and size.** (300g, L×W×H: 142mm × 80mm × 40mm)
- **Channel capacity.** 32 channels of physiological data with two integrated oximeter channels.
- **Channels 1-4** are specialised for DC signals and channels 29-32 have very low frequency high pass filters of 0.05 Hz for recording low frequency signals.
- **Digital filtering** provided on collection and review of the data.
- **Selected sampling rates.** Between 4 – 512Hz.
- **16 bit resolution**
- **Serial infra-red communication** for configuration and control.
- **Radio Local Area Network (LAN)** to communicate with base station computer for real time monitoring and local recording.
- **Records to** a 128Mb compact flash card (ambulatory monitoring) or to a computer hard disk (local monitoring).
- **Local monitoring** is performed with a desktop/laptop computer.
- **Completely software controlled** for configuration (Siesta Online) and monitoring (Perfusion PSG).
- **Powered by a** nickel metal hydride rechargeable battery or 4 standard AA batteries and can operate for up to 48 hours.
- **A pack of standard electrodes** and provided by Compumedics sensors for sleep studies, was used for this study.
- **Provided that sensors/transducers** can be interfaced with the Siesta, recording of any desired signal is possible.

**Parameters measured**

In the current study measurements undertaken included:

- **ECG (electrocardiogram)** – recording of the fluctuations in potential that represent the algebraic sum of the action potentials of myocardial fibres;
- **Surface EMG (electromyogram)** – recording of the electrical activity of muscle;
- **Respiration** – a respiratory band that uses a piezo electric transducer to sense the change in circumference of the thorax or abdomen;
- **Pulse oximetry** – absorption of light passing through tissue is mathematically related to the amount of oxyhaemoglobin in the tissue, and the pulse oximeter eliminates the constant absorption due to tissue and other components and measures only the absorption of pulsatile arterial blood. Finger nail attachment was used in this study;
- **Muscle spasms** – piezo electric transducers (accelerometers) are placed on the patients’ legs to monitor muscle spasms.
- **Temperature** – thermistors were placed on the patients’ skin to monitor their body surface temperatures above and below the spinal lesion. These sensors were developed specifically for this study.

**Results**

A sample two minute record from a 60 minute patient record is included in appendix A below. This record included ECG, EMG (differential recordings of the left and right deltoids’ electrical activities), spasticity (two channels for the recording of muscle spasms in the legs), thoracic and abdominal respiration, and pulsed oximetry.

**Discussion**

The discussion here relates mainly to the quality of signals recorded and activity related artifacts.

**Sources of noise and signal corruption**

Every electrical system inherently produces noise signals; these can be reduced by using high quality electronic components and with intelligent systems design.

Artifact or interference is the presence of an unwanted signal that interferes with and corrupts the desired signal. Bioelectric signals are particularly susceptible to noise because in general their magnitude is small (10µV – 50mV) and they are in the low frequency range (0.05Hz – 1kHz).
Electrode motion artifact

This artifact is produced as a result of movement at the electrode/electrolyte interface and at the skin/electrolyte interface. The effects of electrode/electrolyte interface can often be considered negligible as the electrode is made of Ag/AgCl and the electrolyte is a stable gel solution. The effects of the skin/electrolyte interface are more significant as there is frequently skin movement. That is, when a patient moves, the skin stretches and disrupts the ionic reaction between the skin and the gel solution. This artifact is minimised by using a stick on electrode and by preparing the skin prior to recording. However, in ambulatory situations the weight of the leads will result in movement artifact and the electrodes must be firmly attached.

Cable motion artifact

Movement of the cables that connect the electrodes to the data logger produces interference as moving the wires in an electric field results in a displacement current to be generated. This artifact can be reduced by restraining the leads from movement and by minimising the electrode impedance.

50Hz Power mains interference

In the presence of the power mains, alternating currents and potentials at 50Hz can generate an electromagnetic field that interferes with the recording of the bioelectric signal. This type of interference can be reduced by minimising skin/electrode impedance, using amplifiers with high common mode rejection ratio, keeping the leads close to the body and twisting pairs of leads (such as ECG leads) to minimise the size of an induction loop. There is a 50Hz notch filter built into the proprietary software.

Electromagnetic interference

As the monitoring is in an ambulatory situation, it is inevitable that there are other electrical appliances within the vicinity of the monitoring system. The coupling of these electromagnetic field in the monitoring system causes artifacts in the signals and must be reduced by intelligent design of the device and decoupling of the leads.

DC offset voltage

There is always a certain amount of DC signal that is inherent at the input of the amplifier, therefore, the amplifier must have some tolerance for this DC potential (around 300mV) so that an offset voltage is not seen at the output [3].

Artifact from within the body

As there are electrical activities in all parts of the body, it is inevitable that the signals of these interfere with one another. For example, the EMG trace having the ECG trace coupled to it and vice versa. Taking differential recordings to eliminate most of the common mode signal can reduce this.

Future Systems Improvements

1. Further organisation and decoupling of leads to minimise cross talk between signals and other capacitive effects.
2. Individual channel signal improvement and artifact management. Signal specific signal processing will need to be done for the different types of physiological signals to remove the artifacts or interference. For example, precision peak detection for the respiratory signals, and full-wave rectification and amplitude modulation for the EMG waveforms.
3. A log is needed to keep track of all the events that occurred, such as eating, using the toilet, exercising, etc. It is desirable that this is either voice recording or done with push buttons to code the events so that interference with the patients daily activities are minimised. Because tetraplegic patients frequently have difficulty with the use of their hands this will need to be very user friendly.

Future Research

To further understand the physiology of SCI patients during their rehabilitation, other physiological parameters beside those used in sleep studies will need to be monitored. It may require interfacing existing (off the shelf) measuring systems to the Siesta as well as building non-standard measurement systems.

These may include:

- Physiological parameters that can be monitored with existing peripherals
  - Finapress or Portapress for blood pressure.
  - Oedema can be measured by modifying the respiratory bands.
  - Skin pO2/CO2.
  - Sweating

- Physiological parameters that will require building new measurement systems.
  - A continuous and non-invasive blood pressure monitor.
• Distance/work done monitor for wheel chair.

• Abdominal pressure.

• Skin blood flow.

• Body-seat interface pressure monitor.

**Conclusion**

Initial results suggest that while movement artifacts need to be dealt with, a range of parameters can be recorded during periods of activity undertaken by SCI patients. It is therefore possible to undertake longitudinal studies of SCI patients during prolonged periods that incorporate a range of rehabilitation and other natural activities, and to do so over a period of rehabilitation. Studies of this kind are now being undertaken.

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**References**


**Appendix A**