SLEEPATHOME – REMOTE MONITORIZATION OF CHILDREN WITH OBSTRUCTIVE SLEEP APNEA USING PORTABLE CAMERAS

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ABSTRACT
Remote monitoring has the potential to greatly impact many aspects of medical care. Diagnostic techniques for sleep apnea in children are an example of this concept.

The most common type of sleep apnea is obstructive sleep apnea (OSA). There are broadly two ways of diagnosing OSA. One is Polysomnography, which must take place in a specially equipped medical facility. The other uses a portable monitoring system called oximetry, which was developed to facilitate sleep monitorization at home, in an environment closer to the patients’ normal sleep habits. However oximetry generates false positive results for sleep apnea, making it necessary to use Polysomnography for a more definitive diagnosis.

Sleep studies have also been made, using digital cameras and image processing, where it has been shown the feasibility of identifying sleep apneas. This paper describes a portable telemedical system capable of cross-examining audio and image recordings with oximetry data. The goal is to help medical teams in the diagnosis of sleep apnea, by improving the oximetry method’s efficiency.

KEY WORDS
Telemedicine, Machine to machine (M2M) Communication, pediatric Sleep Apnea, Signal and Image Processing, Vital Signals.

1. Introduction

Sleep apnea is a potentially very serious common disorder. In a sleep apnea episode, the breathing stops or becomes very shallow. Each pause in breathing typically lasts 10 to 20 seconds, or even more, and can occur 20 to 30 times an hour. Sleep Apnea occurs because during sleep muscle relaxation occurs and soft tissue in the air ways can collapse, obstructing the air ways and keeping enough air from flowing into the lungs, even as the patient tries to breathe.

When an episode happens, the saturation of oxygen in the blood may drop and the heart rhythm may change. Regular breathing resumes with a loud snort or choking sound.

Snoring and obstructive sleep apnea are frequent problems not only in adults, but also in children and adolescents. One possible solution to this problem is the use of Continuous Positive Airway Pressure (CPAP). The CPAP is a device used to mechanically avoid the occurrence of sleep apnea as an alternative to surgery. Patients apply a nose mask that delivers a positive and regular air pressure which keeps the air ways from collapsing, even when there is relaxation of the soft tissues (Fig. 1). The pediatric variety of Obstructive Sleep Apnea (OSA) deserves special attention because, while there are several parallels between pediatric and adult OSA, there can be severe consequences of OSA in the growth and intellectual development of children.

There are broadly two ways of diagnosing OSA. The first one is Polysomnography (PSG), and it must carried out in a specially equipped medical facility. It monitors many vital signs, including brain waves (Electroencephalography - EEG), eye movement (Electrooculography - EOG), muscle activity or skeletal muscle activation (Electromyography - EMG), heart rhythm (Electrocardiogram - ECG), and breathing function or respiratory effort during sleep. This complementary diagnostic is extremely expensive and the reduced availability of sleep laboratories limits the number of pediatric studies. Another difficulty of performing a PSG study of a child is that the performance
and interpretation of results have not yet been standardized or evaluated for different age groups [2]. Sometimes the results achieved with PSG are not a true reflection of reality because the patient is sleeping outside his or her normal environment. The problem is compounded in children. The other diagnostic method uses a portable monitoring system based upon pulse oximetry. Being portable, it allows monitoring of patients’ sleep in their home, making the study easier, more comfortable and closer to the patient’s normal sleeping habits.

Simple oximetry gathers less information (oxygen saturation and heart rate alone) than what can be obtained in a PSG study. Sometimes, children with negative results from pulse oximetry still require a complete nocturnal PSG for a complete diagnosis [3][4].

This proposed system will improve the diagnostic methods and ease the treatment. By outfitting patients with a portable system, capable of collecting detailed real-time data on physiological statistics, the patient's quality of life can be greatly increased.

2. Project Description

Studies of sleep apnea using cameras show that it is possible to identify apneas using adequate image processing techniques [1].

Therefore, one of the objectives of this paper consists in the synchronization of video and audio recordings with pulse oximetry data (Fig. 3) in order to help the medical staff in the diagnosis and classification of sleep apnea in children.

Another goal is to improve the efficiency of oximetry in OSA diagnosis through the use of a camera to automatically detect apneas by looking for abnormal child movements. There are a few telltale signs that can be looked for, such as head movement, open mouth or abnormal extension of neck that precedes repetitive arousals.

The third and most ambitious goal is the development of an expert system, which uses artificial intelligence techniques to correlate data from oximetry, cameras and other monitoring devices in order to help doctors identify patterns and usual scenarios. The information will be used to pinpoint to the medical staff patients that require special attention, generating alarm reports. The system is able to detect situations where sleep does not have the desirable duration, where there is systematic interruption and where there are sleep apneas in spite of constant airflow. It will also detect abnormal irregularities during the night that require attention, such as an unjustified movement of the patient without apparent reason. In those cases, correlation of recorded images and sounds of the patient's movements with clinical data from the sensors is an important tool for the medical staff in investigating the reason for the incoherent data or patient behavior.

It is important to stress that this system is not intended to replace PSG but it would be very useful when collecting information at home. The system intends to identify patients that should be later submitted to PSG observations in a hospital setting, using an easier and cheaper method.

The application ensures that all data is stored in a database, together with the patient medical chart, for future reference.

3. Remote Monitorization – System Architecture

The SleepAtHome system is composed of a setup for the acquisition, processing and transmission of data from medical devices used in sleep apnea diagnosis (Fig. 2). The modular architecture of the system allows for real-time monitoring and follow-up, reducing the costs associated with the diagnosis and treatment of OSA. It uses simpler alternative diagnostic methods, permitting its
deployment in a child's familiar environment. The most promising data used in children are audio and video streams, oximetry levels and electrocardiograph traces [3][5]. This concept of diagnosis and remote monitorization could later be widened to a greater set of clinical devices, such as EEG and ECG.

4. System Interface

The system can be easily accessed both locally and remotely through a PDA, where alarms and oximetry information are displayed (Fig. 4) using machine to machine (M2M) communication. Reports, full diagnostic tests and historical patient data can be accessed from the data warehouse through the datacenter, using a Web interface. The data is encrypted to assure patient privacy and can only be accessed after authentication.

Fig. 4 – PDA Access Interface.

5. Discussion

The efficiency and accuracy of portable monitoring systems based on oximetry measurements can be enhanced by also monitoring sounds and adjusting image capture through a motorized infrared video surveillance camera. Using the described method, oxygen saturation levels could be correlated with a child's position while detecting if the nose and mouth are unobstructed with the blankets and pillows. The camera positioning motors could keep track of movements, ensuring the system is always able of monitoring the patient in spite of his or her movements.

6. Conclusion

Even though this system is especially concerned with OSA in children it has the advantage of being easily adapted for adult home use, while maintaining its portability. The concept of diagnosis and remote monitorization could later be widened to a greater set of clinical devices, such as EEG and ECG. This opens new fields of application, such as monitorization of patients with heart conditions or patients recovering from recent heart surgery.

The equipment's mobility is important because it improves the diagnostic methods. By outfitting patients with a portable system capable of collecting detailed real-time physiological data, quality of life can be greatly improved.

One possible limitation is that the patient can leave the camera's field of vision due to his or her movements. This could be overcome with the inclusion of a robotic arm to more efficiently track the patient's movements. This approach, used in conjunction with PSG, can further enhance sleep laboratory studies. However the latter approach implies a less portable system.

References

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