Monitoring of preterm infants during crying episodes

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Abstract— **Preterm infants often suffer from respiratory problems. Crying is an effort which may have an adverse impact on blood oxygenation. In this work we present a measurement system aimed at the evaluation of the distress occurring during cry, giving a quantitative measure of the decrease of cerebral oxygenation. The system allows to monitor the central and the peripheral oxygenation, together with an audio recording of vocal emissions by the infant. Preliminary results on a data set of 15 preterm infants indicate that in some cases the effort is associated with a large decrease in the oxygenation level during a cry.**

Keywords— **NIRS, pulsioxymetry, infant monitoring, vocal analysis.**

I. INTRODUCTION

Infant monitoring in Neonatal Critical Care Unit is a common practice in clinical procedure. The most frequently used monitoring instrument is a pulsioxymeter, which provides a non-invasive way for monitoring heart rate and peripheral blood oxygenation.

Low birth weight infants, indeed, often present respiratory problems, ranging to insufficient ventilation to apnoea. At the same time, the cerebral blood flow in preterm infant and in the new born has been studied extensively [1,2] as new born infants have an impaired autoregulation of the cerebral blood flow [3,4]. Irregularities in the blood flow and pressure may adversely influence the development of the child [5,6,7,8].

Several studies indicate a correlation of respiratory problems with neurological problems during the growth of the patient [9,10]. Some studies have been performed in order to evaluate the blood flow and oxygenation in the new born by Near InfraRed Spectroscopy (NIRS), also linked with other techniques [11].

One of the most common events that may affect the respiratory flow is related to cry. Crying is a physiologic action for the infant to communicate and to draw attention, however this action requires a great effort for a premature infant, which may cause distress. In this work, we evaluate the correlation between the cerebral oxygenation and cry, by a non invasive monitoring performed simultaneously with a NIRS spectrometer and a pulsioxymeter.

II. MATERIALS AND METHODS

A. Data set

The analysis has been carried out on a group of preterm infants, having a gestational age ranging from 28 to 34 weeks. Infants were selected by a physician among patients hospitalized in the Critical Care Unit of the A. Meyer hospital in Florence. The measurement session took place on patients having an age between 3 and 4 months.

At present, a preliminary data set has been analyzed, in order to assess the information which can be collected and to optimize the experimental setup. This preliminary data set is composed of 15 patients, whose relevant information is reported in Table 1. A control group, composed of 20 patients, has been used as a reference to evaluate the physiologic ranges of the parameters.

Table 1 Data set

Minimum gestational age	27 weeks
Maximum gestational age	36 weeks
Minimum birth weight	1.400 Kg
Maximum birth weight	2.100 Kg

B. Instrument setup

Monitoring has been performed by collecting data from three different sources: heart rate and peripheral blood saturation of oxygen have been measured using a pulsioximeter (3900 - Datex-Ohmeda), central blood saturation has been measured with NIRS (ISS Model 96208 - ISS Inc., Champaign, IL USA), and a microphone has been used to record cry emissions.

An important issue which arised during the experiments was related to synchronization among the three sources: in order to correctly relate cry and oxygenation pattern it is essential to obtain a strict synchronization among the instruments which have been used for monitoring. Moreover, the NIRS device we used is not equipped with an output signal which may be used to transfer data in real time to a recording device. The device has 4 analog inputs which are sampled and acquired during the measure, and a sample rate of 1 sample/second. Those inputs can thus be

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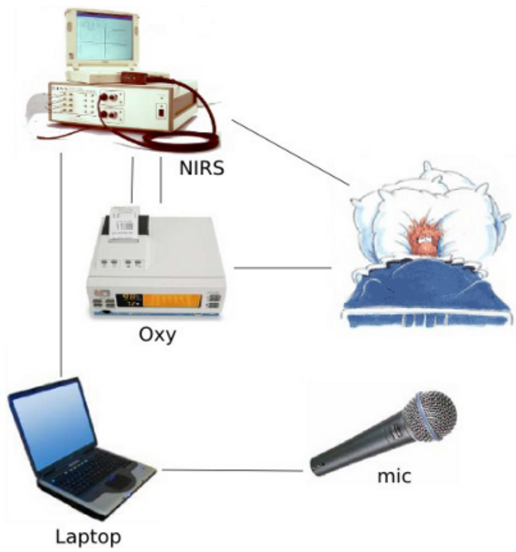

Fig 1. Acquisition system

used to acquire data from the pulsioximeter, which has a similar transfer rate.

Audio recording was performed using a multimedia laptop which acquired a single channel audio track, sampled with 12 bits of depth and a sampling rate of 44KHz. An acquisition software has been designed to allow synchronization with the other instruments using a digital output linking the laptop with the input of the NIRS instrument. This acquisition software transforms the single channel data into a two channel signal, where one channel (left signal) corresponds to the acquired waveform, while the other channel contains a synchronization binary pattern, which is at the same time emitted on the digital output. This pattern is recorded together with NIRS and pulsioxymetry signals, allowing to synchronize the two recordings. The overall diagram of the experimental setup is shown in Fig. 1.

C. Data acquisition

Data acquisition may be adversely affected by environmental factors and by the patient itself. As concerns the environmental factors, the NIRS acquisition may be altered by different levels of light in the acquisition room. In order to ensure a good quality of data, a careful selection of environmental condition is required. A room has been selected in the Intensive Care Unit, satisfying all the necessary requirements:

- Low background noise, as the room is far from noise sources and it can be successfully insulated from the outside.
- Levels of illumination can be selected accordingly to the instrument requirements

Fig 2. Positioning of the sensor on the child head (simulation on a doll)

Moreover, both instruments are sensitive to movement artifacts, as the patient may perform sudden movements. To reduce such disturbances, special care has been used to assure a good contact between sensors and the patient skin.

As concerns the factors related to the patient itself, we considered the possible effects of the physiological situation on the measurements. To improve the reliability of data, we performed all the measurements at the same time of the day, and equally spaced between meals. A second factor is related to the positioning of the NIRS sensor on the head of the infant. The size of the sensor is comparable to the mean size of the head of the infant (as described in Fig.2, referring to a doll having about the same head size), so a careful positioning and securing of the sensor on the subject is required.

D. Data processing

Acquired data exhibit two kind of noise: high frequency noise, with a small amplitude, caused both by intrinsic variability of the data, variations of the blood volume due to the pulsation of the flow, and sampling effects, and spikes, having a large amplitude, caused by movements of the patient. The first part of the analysis is therefore aimed at reducing the effect of noise.

A first filter has been used to detect and remove spikes from the input signal. The filter has been designed using an heuristic method, from the study of the variance of each signal on a window of a predefined length. A sample has been assumed to belong to a spike if the difference from the previous one is larger than twice the standard deviation of the signal. When a sample belonging to a spike is detected, it is removed from the signal by substituting its value with the last sample before the beginning of the spike. This simple solution allows to remove spikes having a very sharp peak, which can be associated to problems related to the contact of the sensors with the skin, preserving large signal variations due to alterations of the physiological state of the patient.