pulse oximetry,
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COMPUTERISED SYSTEM FOR OXYGENATION MONITORING IN NEWBORN INFANTS

The main task of neonatal monitoring is measurement of oxygen saturation of arterial blood. At present, the pulse oximetry is commonly used. Around the clock controlling several monitors, usually distributed in different rooms within neonatal care unit, is extremely uncomfortable for the clinical staff. Solution of this problem can be the development of the surveillance system for continuous monitoring of newborns to early recognize risk for their life. Such system is able to present data from all newborns being monitored on one screen of the central monitoring station. Additionally, the system performs the on-line analysis of acquired signals and alerts when situation hazardous for the newborn life is detected.

1. INTRODUCTION

The basic risk for health and life of premature baby is associated with its respiratory insufficiency. The measurement of the oxygen saturation of arterial blood enables estimation of the level of the risk of hypoxia. This measurement is mainly accomplished by the pulse oximetry [2]. Continuous monitoring the oxygen saturation allows controlling a response to administered drugs and if necessary changing the treatment procedure. This is very essential in neonatal intensive care unit (NICU), where very often oxygen has to be provided to newborn baby for the significant time period.

Considering continuous growing of the number of premature babies a simultaneous monitoring of several patients is at present very typical situation in the NICU. Continuous observation of the biophysical data from distributed bedside monitors and reaction to, very often accidental, alerting situations are very uncomfortable for the clinical staff, may decrease its efficiency and take a lot of valuable time which can be spent doing direct neonatal care. It is very difficult to make relevant decision when alerting situations are recognized by several pulse oximeters at the same time. This increases the possibility the situation hazardous for newborn's health or even life will be missed. It has been showed that there was no reaction to 65% of all monitors alerts in the NICU [1]. Equally often the monitoring session is interrupted because of too weak signal, patient's movement or sensor contact lost.

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Solution of above problems is the development of the centralized system for continuous monitoring of newborns, which offers a number of additional features that are inaccessible in conventional monitoring [4].

2. THE SYSTEM DESCRIPTION

In the proposed monitoring system for neonatal care the following biophysical signals are measured: instantaneous value of oxygen saturation of arterial blood (Sp02), pulse rate (PR) and plethysmographic curve. These sampled signals are captured from the output of a pulse oximeter and via interface unit they are transmitted to the computer of the central monitoring station (Fig. 1). The incoming data are on-line analyzed, visualized on the computer screen and stored in the system archive. Originally, the system cooperates with the PxOM-300 pulse oximeter (ITAM Institute, Zabrze). This monitor is based on the all-in-one PC and the measurement module (Fig. 2). The X-Board 861 PC unit has the AMD 266 Hz microprocessor, graphic card, 32 MB DRAM and 32 MB Flash RAM integrated in one chip. Thanks to a small size of the PC unit (W×H×D: 68×8×49 mm) the size of the pulse oximeter could also be reduced. The PC unit controls the signal acquisition process by capturing the data from measurement module as well as manages their further analysis and visualization for the user. The sensor and the OEM 701 measurement module are off-the-shelf products provided by Dolphin Medical. Measurement module is based on DSP technology accomplished by a high speed 128 MHz RISC processor. The module applies the Fast Fourier Transform (FFT) to identify and reject artifacts associated with a patient's motion. The FFT-based analysis results in improved performance with low-perfusion patients, and reduces the frequency of nuisance alarms. The module measures SpO2, PR, and temperature on adult, pediatric and neonatal patients. Additionally, Dolphin Oximetry sensors provide information to the OEM-701 module in digital form, instead of the more traditional low-level analog signals, thereby eliminating corruption of the sensor waveform by external electrical noise sources.

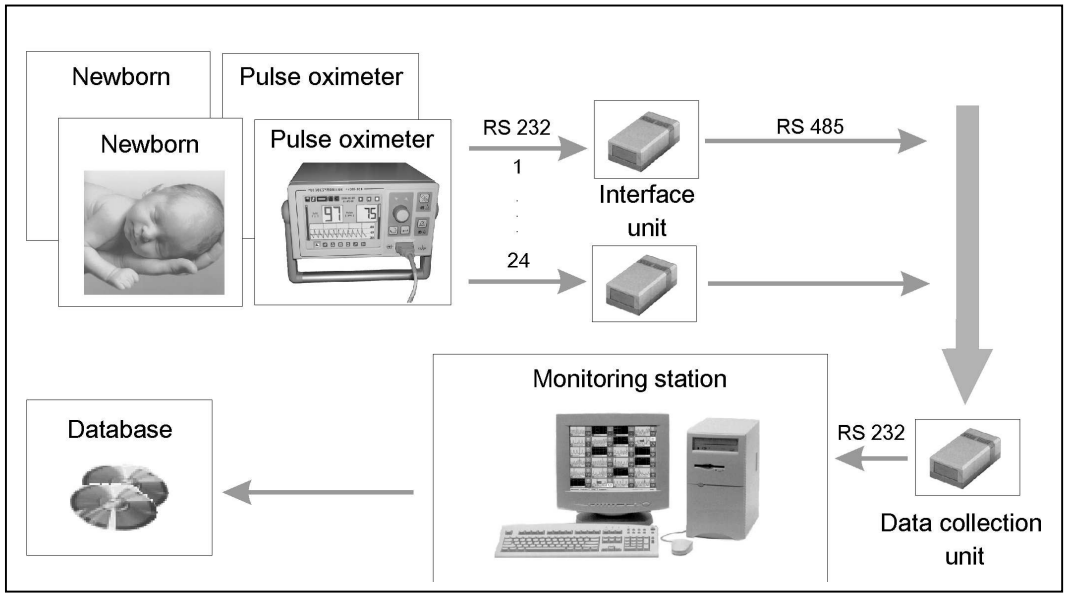

Fig.1 General structure of the neonatal monitoring system.

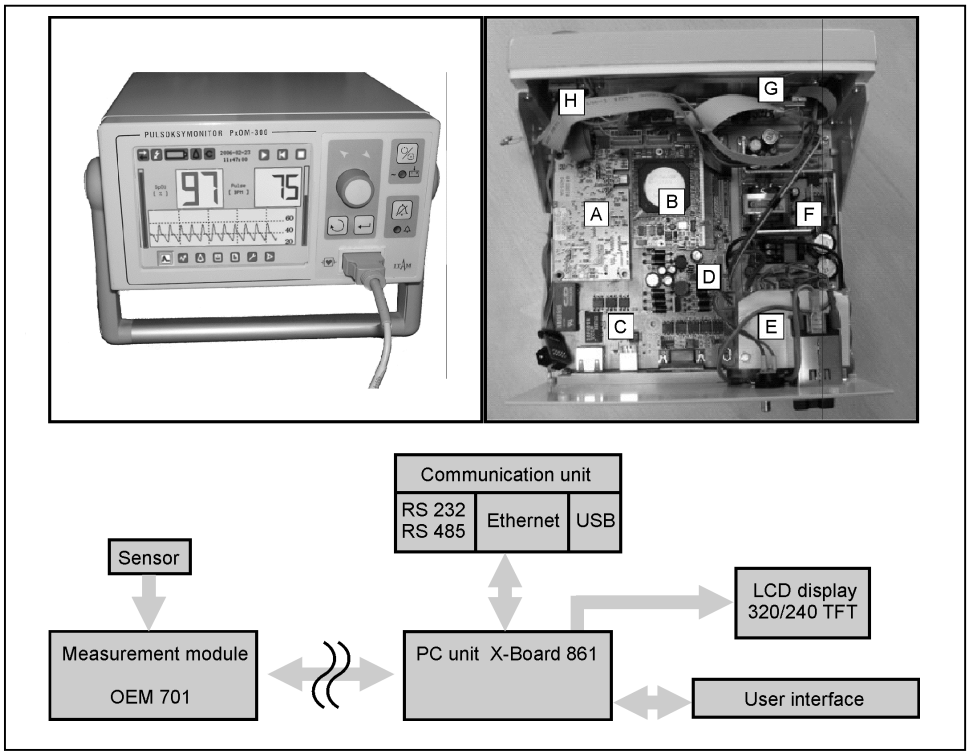

Fig.2 The front panel and the inside view of PxOM-300 pulse oximeter showing the particular functional modules. The block diagram below comprises: A – measurement module, B – PC unit, C – galvanic barrier, D – main board power supply sockets, E – rechargeable battery, F – medical power supply unit, G – LCD display, H – the user interface and sensor socket.

The PxOM-300 oximeter ensures the measurement of SpO_2 in the range of 0 ÷ 100 % (with resolution of 0.1%) and PR in the range of 30 ÷ 240 (with resolution of 0.1). Trends of the changes of measured signals as well as plethysmographis curve can be store in the monitor memory. The resolution of the built-in LCD display is 320×240 pixels.

Also, the pulse oximeters from other manufacturers can be used as input devices, that enables the best use of equipment being in hospital's possession. Both hardware (various transmission link) and software (various communication protocols) adjustment is accomplished by microcontroller-based interface unit [3]. Thanks to optical barrier it ensures a full patient's safety. The communication protocols of all commercially available monitors have been implemented. Data obtained from monitors of different type are transformed into uniform format and sent to the computer according to one established communication protocol. Such approach prevents the computer communication software from any modifications which usually are necessary when pulse oximeter of a new type is to be connected to the system. The length of data block is equal to 43 bytes. Therefore, from the computer side, every bedside monitor looks the same. Information of the monitor type is included in the data block. Data blocks from all monitors are transmitted to the computer in 1 sec intervals. The number of monitors connected and established data block length define the minimum value of transmission baud rate. We established transmission speed at 19200 baud, which is enough to get data from 24 monitors connected to the computer at the same time. Adapting new pulse oximeter (of a different communication protocol) to the system comes down to a simple modification of the microcontroller software and, if it is necessary, changing the socket in the interface unit. All these changes can be carried out during the system works e.g. without

switching it off. This is very important taking into account the system application in the neonatal intensive care unit. The appropriate communication protocol is selected automatically by the microcontroller of the interface unit thanks to the monitor identification procedure.

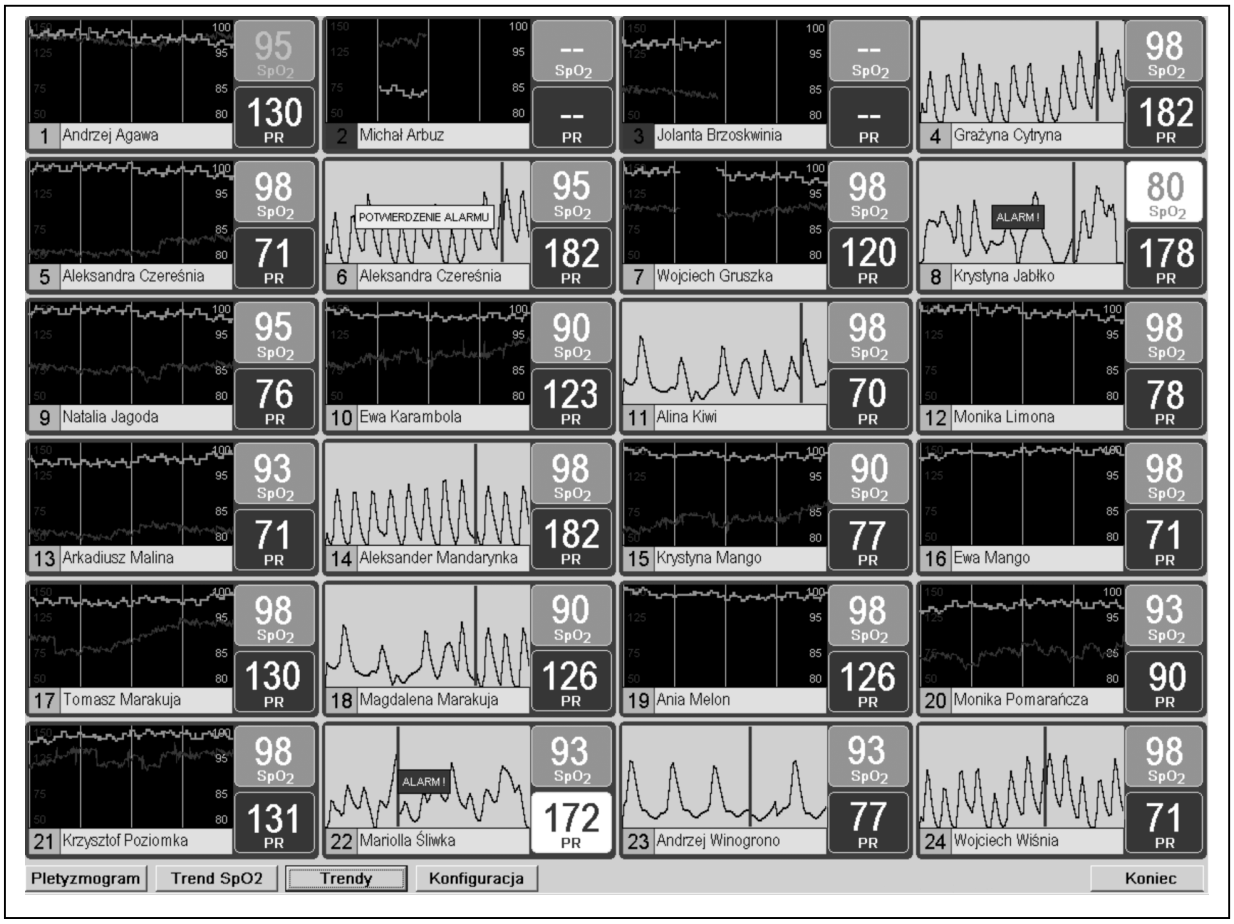

Fig.3 The system window for simultaneous presentation of the on-line data from 24 patients.

Up to 24 bedside monitors can be connected to the system at the same time. This amount is enough even for big intensive care unit. Access of several monitors to one RS-232 connector of the computer is enabled by the data collection unit, which multiplexes bedside monitors. Data collection unit is transparent for the data from monitors. Each interface unit with associated pulse oximeter is identified by its exclusive number. This number is used by the data collection unit, which periodically sends permission for transmission to successive monitors. Wall-mounted sockets for monitor connection are located anywhere within the NICU. Data transmission between interface unit and data collection unit takes place trough the RS-485 serial link whereas between data collection unit and computer via RS-232 link. It ensures reliable transmission on long distances and simplifies system wiring.

Biophysical data from all newborns being monitored are presented on the monitoring station screen. Fig. 3 shows the screen divided into 24 windows corresponding to the connected monitors. The display form has been designed to make alerting situations easy recognizable for the clinical staff. Considering the staff's habits the data are presented on the computer screen in the same form like on the front panel of pulse oximeter. In each window the instantaneous values of oxygen saturation and pulse rate are presented in numerical form. Additionally, the plethysmographic

waveform is plotted from the last four seconds with the automatic scale adjustment (Fig. 3, window no. 4). It is possible to switch each window to display the trends of SpO2 and PR changes over established time interval, for example 30 min (Fig. 3, window no. 1).

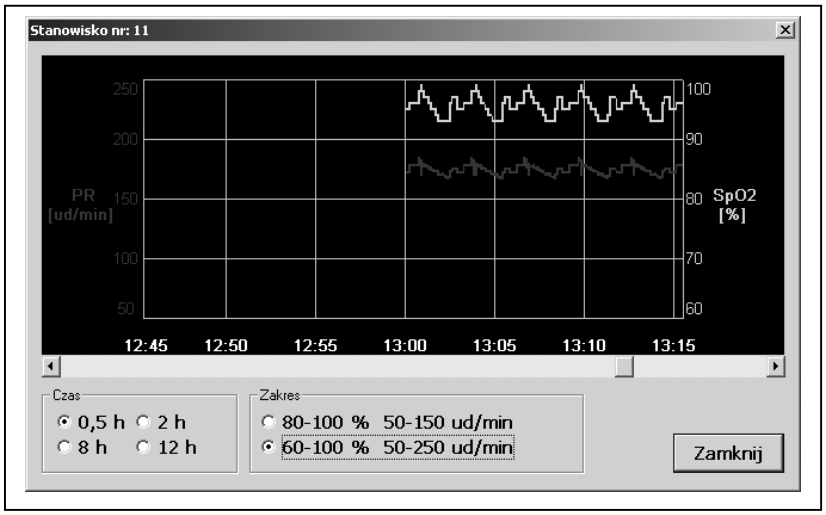

Fig.4 History of monitoring presented in the selected time interval and signal range.

During monitoring, the signal values acquired from all monitors connected are stored in the system archive, as well as the trends of their changes. It enables retrospective analysis of the trends from any selected time period in the last day or week. This is very helpful both for scientific work and for possible legal proceedings. The trends can be displayed using four time scales and two vertical axis scales (Fig. 4).

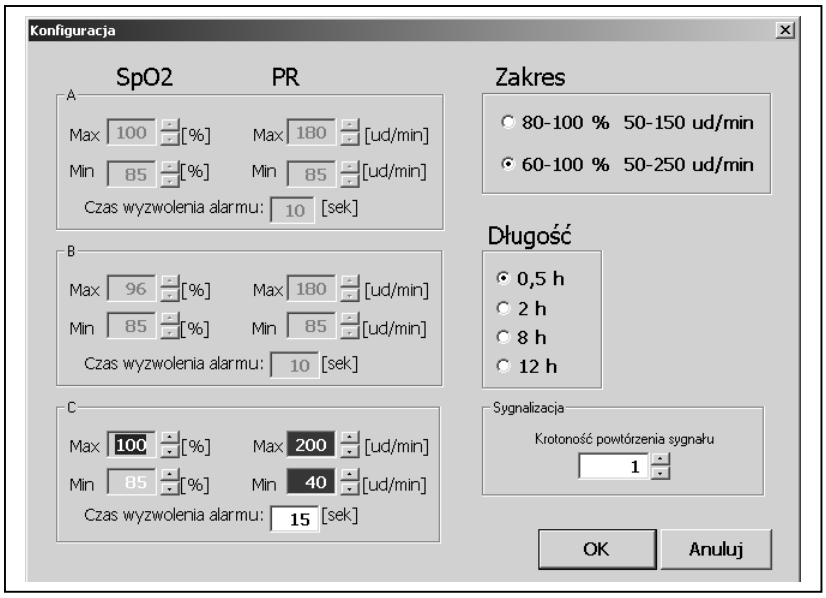

Fig.5 Window for configuration of alert limits and forms of trend presentation.

Recognition of alerting situations and warning the clinical staff of their occurrence is the main feature of the system for central patient surveillance. As for the neonatal monitoring the alerting situation occurs if at least one of the measured parameter (SpO2 or PR) exceeds the established

limits. The alert limits are defined in a form of ready-to-use sets, for example standard set or the set for newborns that are provided with supplementary oxygen. It is possible to define an alert delay, which prevents from unnecessary warning if the limits are exceeded only for short time, for example due to newborn movement. Apart from the alerts from physiological reasons the system notifies about technical alarms that are provided by the bedside monitors, for example if the sensor location is not proper.

Communication between the user and the system is carried out through graphical user interface (GUI). Possibility of configuration of the system work parameters is very crucial, since it allows matching the system to the user requirements. Figure 5 shows the configuration window which enables the SpO2 and PR alarm limits to be defined in three sets (predefined A, B and user-defined C). The user can also select the default time and vertical axis scales for the trends.

3. CONCLUSION

Diagnostics of newborn baby is aimed at early detection of insufficient oxygen supply to tissues. The level of hypoxia can be evaluated by means of measurement of oxygen saturation in arterial blood, which is carried out by the pulse oximetry. Continuous observation of the biophysical data from distributed bedside monitors is extremely uncomfortable for the clinical staff. Solution of this problem is the computer-aided system which acquires data from pulse oximeters (up to 24 monitors in our approach), performs on-line analysis of incoming data, stores and presents them on a screen.

The most important feature of the system is detection of alerting situations when value of at lest one of the measured parameters exceeds the limits established by the user. The developed system improves the work condition of medical staff and thereby increases the quality of clinical treatment in the neonatal intensive care unit.

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