CONTINUOUS COLLECTION OF PULSE OXIMETRY DATA: A NEW, INEXPENSIVE, PORTABLE COMPUTERIZED METHOD

A. L. RONALD, G. P. RAMAYYA AND W. A. CHAMBERS

SUMMARY

The availability of reliable pulse oximetry equipment has led to interest in identifying patterns of hypoxaemia in the postoperative period. Methods for the computerized collection and analysis of pulse oximetry data have been described, but these require continuous use of a relatively powerful computer system throughout both the monitoring (data collection) and analysis periods. We have designed a technique which uses a small, portable and relatively inexpensive computer unit for data collection, after which the data may be transferred to a more powerful computer for analysis. Appropriate programming and choice of software have produced a relatively "user friendly" system which can be operated successfully even with minimal computing experience. The unit has the potential to be modified to form the basis of a "medical advice system" which could be used for the "intelligent" monitoring of high risk patients.

KEY WORDS


It is well known that many patients suffer from episodes of hypoxaemia in the postoperative period. Anaesthesia induces physiological changes in the lungs which may contribute to episodes of arterial oxygen desaturation in both the perioperative and the postoperative periods [1, 2], and these effects may be compounded by particular analgesic regimens [3–5]. The introduction of pulse oximetry has facilitated the continuous non-invasive monitoring of arterial oxygen saturation, and a method has been described by Wheatley, Somerville and Jones for the computerized collection, analysis and display of oximetry data [6]. This technique involves connecting an oximeter to an IBM-compatible Personal Computer with a 20-megabyte hard disk while data are collected, after which the data are analysed and displayed by the computer. Unfortunately, this method is rather expensive and wasteful of computing time, so we have adapted the technique to use a small, portable and relatively inexpensive "pocket computer" for the collection of oximetry data. After collection, the data are transferred to a standard desktop PC for analysis.

APPARATUS

The DIP pocket computer (Distributed Information Processing, Guildford) is used to collect oximetry data. This is a true "pocket" computer, measuring 10 × 20 cm when closed, and weighing 450 g. It opens up in a manner similar to a laptop computer, to reveal a supertwist liquid crystal display (LCD) which accommodates a 40-column by eight-line display, and a "QWERTY" type, positive-keypress keyboard. The computer contains a 80C88 processor running at 4.9 MHz and its PC compatible Basic Input Output System (BIOS) and MS-DOS-like disk operating system give it a high degree of functional similarity and compatibility with IBM type PCs. In addition to mains operation, it operates from three size AA alkaline batteries.

The DIP Pocket PC contains an internal RAM disk drive of 128 KB, but it also accepts solid-state, credit card sized memory cards into an additional drive in a manner similar to that in which a desktop PC accepts floppy disks. Standard memory cards store up to 128 KB of data, although larger capacity cards of up to 4 MB are currently under development. Each card contains a lithium battery with a lifespan of 1–2 yr, and a card can be used to store valuable data for prolonged periods of time. By fitting a memory card reader device into a free 8-bit expansion slot on an IBM-compatible desktop PC, memory cards may be used to transfer data rapidly between pocket and desktop computers.

In addition, the DIP Pocket PC contains an expansion bus connector which accepts various optional peripherals. Appropriate serial and parallel interfaces allow the computer to communicate with printers, modems or even directly with desktop PCs.

For pulse oximetry studies, a 128-KB DIP Pocket PC is interfaced with an Ohmeda Biox 3740 pulse oximeter using a DIP serial interface and cable (fig. 1). A standard finger probe is used to connect the oximeter to the patient. A computer program, written in assembly language by one of the investigators (G.P.R.), programmes the pocket PC to log from the pulse oximeter strings of data consisting of heart rate, saturation and an alarm status code. The

Fig. 1. DIP Pocket PC interfaced with oximeter.

alarm status code allows subsequent identification of alarm states resulting from technical problems, including probe disconnections or insufficient light detection. The program was transferred on to, and subsequently run from, a 128 KB memory card, where it occupies 2753 bytes of card space. With a logging interval of 20 s, 51 h of data can be collected on the remaining memory card space. Starting the program records the start date and time from the computer's integral clock, and running the program creates a data file on the memory card. The program may easily be modified to increase or decrease the sampling interval; however, this obviously affects the maximum duration of the study period.

At the end of any study period, the data file on the memory card is transferred to an IBM-compatible desktop PC via a memory card reader and imported into the spreadsheet Excel v 3.0 (Microsoft Software) for analysis. From the initial data file, simple graphs can be drawn of heart rate and oxygen saturation, using the basic spreadsheet facilities, but specific Macros have now been written which allow more complex automatic analysis and display of data in specific forms. (A "Macro" is a small program consisting of a series of spreadsheet commands which, when run, performs a specific analysis.) The data are analysed to produce a frequency distribution table of saturations for each 1 h of study. This part of the analysis recognizes and ignores aberrant results which result from technical problems during the monitoring period, by identifying their appropriate alarm status codes. Episodes and degrees of hypoxaemia can be defined and Macros used to determine the number and duration of such episodes. Macros may also be used to produce complex graphs of oxygen saturation vs time as described by other authors [6], and to analyse heart rate changes during hypoxaemic episodes.

The initial Macro which converts the oximetry data file into a frequency distribution table takes 15 min to analyse 48 h of data, using a 386SX PC running at 16 MHz. The analysis software also operates on 286-based PCs, albeit more slowly. However, once started, processing is automatic and the continued presence of the investigator is not required. Analysed data files, spreadsheets and graphs may be stored easily on disk for subsequent rapid retrieval.

This system of continuous pulse oximetry data collection and analysis was assessed initially using the investigators as subjects. However, we have now commenced a series of clinical studies in which the system is used to collect continuous oxygen saturation data from patients in both the pre- and postoperative periods and, to date, it has been used to collect more than 100 patient-days' worth of data. In practice, there have been no significant technical problems in collecting these data and the system is currently being analysed fully.

DISCUSSION

Techniques for computerized data collection and analysis have been described, but they have required a standard IBM-compatible PC for both the monitoring and analysis periods. Our system has several advantages.

Each monitoring unit is relatively inexpensive (DIP Pocket PC £170; Serial interface £50; 128-KB memory card £100; memory card reader £60). The system is extremely portable and can be moved easily from patient to patient. Simple modifications to the
program allow it to be used with other oximeters which have a serial interface port.

An IBM-compatible PC is required only for data analysis. Therefore, the system does not demand sole use of a powerful dedicated computer for prolonged periods of data collection. Although we currently use 386-based computers for data analysis, Windows and Excel also operate on slower, 286-based machines. One PC fitted with a card reader and the analysis software is able to service multiple data collection units. Therefore, for many potential users of such a system, existing computers can be modified easily to enable transfer and analysis of memory card data. Minimal computing knowledge is required to use the system as Pocket PC set-up is easy, and the use of simple batch files ensures that all necessary set-up information (date and time) is entered correctly and logged when the program is started. The spreadsheet analysis software Excel operates within the mouse-driven Microsoft Graphical User Interface, “Windows 3.0”. Excel and the analysis Macros are started using the mouse, and once they have begun, the continued presence of the investigator is not required. Further Excel Macros may be written to carry out other analysis of the oximetry data.

The pocket computer may also be interfaced to any monitor with an RS232 serial output and similar programs written to collect other physiological data. Unfortunately, each pocket PC can collect data only from one serial output. However, in the future, it may be possible to use the system to simultaneously collect several types of physiological data from the single serial output of a multichannel monitor. This would, for example, facilitate the analysis of simultaneously obtained heart rate, arterial pressure and oximetry data from a suitable monitor.

The major disadvantage of the system at present is the limited memory capacity of the 128-KB memory card. However, with a sampling time of 20 s, we are able to collect up to 51 h of data on one card (equivalent to about 9000 readings). This sampling time can be altered easily, although more frequent sampling decreases the maximum possible study period duration. Memory cards of up to 4 MB capacity are currently under development and their introduction may allow more frequent and more complex data logging over longer periods for subsequent analysis.

This system has considerable future potential. Even with the present memory limitations, there is the capability to program intelligent alarm systems into the computer. Simple rule structures may be incorporated into a program to define “critical events” such as particular degrees of hypoxaemia and, by continuously analysing the data as they are collected, intelligent alarms can be triggered if any such events occur. These alarms could be used to display treatment options on screen, and in this situation the computer would behave as a medical “advice system”. A system which is able simultaneously to collect and analyse data, and suggest appropriate therapeutic interventions, has obvious applications, not only in the management of the postoperative high risk patient, but also in other fields of medicine and intensive care.

ACKNOWLEDGEMENT

We thank Rhone-Poulenc Rorer Pharmaceuticals for their financial support in developing this system.

REFERENCES