International Journal of Clinical Monitoring and Computing **9**: 221–227, 1992.

Neonatal physiological trend monitoring by computer

S. Cunningham, S. Deere, R.A. Elton* & N. McIntosh
Dept. of Child, Life and Health, University of Edinburgh, 17 Hatton Place, Edinburgh, EH9 1UW, UK;
** Dept. Medical Statistics, University of Edingburgh, UK*

Accepted 11 May 1992

Key words: computer, intensive care, newborn, trend

Abstract

A premature baby born up to four months early is a fragile patient dependent on intensive care. The body systems are physiologically immature and so tolerate stress badly. The tendency of these infants to rapidly deteriorate, has led us to use a cotside computer monitoring system which displays physiological trends. Information from standard neonatal monitors is accessed by individual cotside PC's linked to a central network server and Doctors terminal. Trend graphs can be easily manipulated, displaying from 7 minutes to 3 days of physiological information on a single screen. Pathology may be observed in real time as it occurs. The system has 3 main areas of use, (1) as a real time clinical aid to patient management, e.g. apnoea of the newborn; (b) as a research tool, demonstrating the effects of procedures on physiology; (c) for educating members of staff about how physiological events develop. Data is saved for the whole of each neonates intensive care stay. Assessment of staff and parent attitudes by questionnaire have been favourable.

Introduction

Routine critical care management has been assisted by the development of computers. This involves not only the routine charting of physiological parameters and biochemical results but also the development of expert systems to detect and warn of patient instability. Whilst it is recognised that Intensive Care areas lend themselves to computer involvement [1], it is essential that computers are not used simply because they are advanced technology and imperative that they do not interfere with direct patient care [2]. It is equally important that the life span of the computer system is not limited to that of the motivating figure within the unit [3]. Medically orientated computer programmes should be simple in presentation with easy access [4]. If these criteria are not matched, computers will compound the considerable stress recognised in such units and increase the rate of staff turnover.

Neonatal intensive care could benefit greatly from computer assisted care. As yet however, there has been very limited development in comparison with adult intensive care areas. It is now possible for neonates born as early as 24 weeks gestation and weighing as little as 500 grams to survive. The risks associated with promoting such survival are potentially very significant and include; sepsis, cerebral intraventricular haemorrhage, acute and chronic pulmonary problems eg. blocked ET tube, pneumothorax, bronchopulmonary dysplasia and spontaneous apnoea. Such events may be frequent in small, immunologically and physiologically immature infants. There is often little warning of deterioration and without immediate resuscitation death or serious handicap may result.

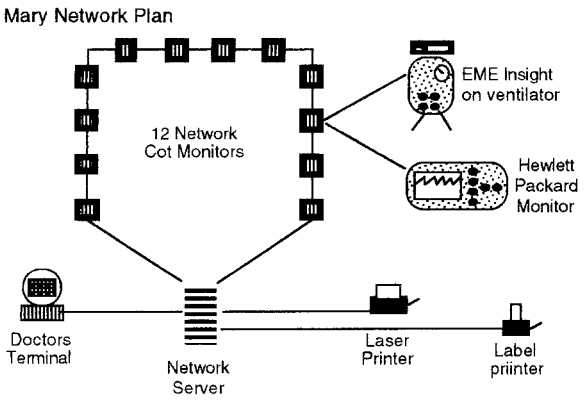

Fig. 1. Mary Network Plan.

Computer monitors for Neonatal Units must differ from their adult counterparts for several important reasons:

(a) the sick neonate is relatively invisible, often hidden by bubble plastic, enclosed within an incubator and discoloured by blue phototherapy units
(b) the fragile infant requires as little handling as possible to ensure thermal and fluid stability [5] and to allow adequate rest between potentially frequent handling procedures [6].
(c) neonatal units often have a 1 : 2 or 1 : 3 nurse/patient ratio, whereas adult ITU has a ratio of least a 1 : 1
(d) deteriorations in sick neonates are often acute over seconds or minutes. They occur with apparent suddenness partly at least because of the inability of the neonatal patient to verbally indicate deterioration but also because of the immaturity of neonatal homeostatic mechanisms.

In essence, because a neonatal patient is poorly visible and unable to communicate deterioration, clinical information may frequently be limited to the physiological parameters measured on monitors. For nurses who have to cope with more than one poorly visible intensive care patient at one time, computers could assist by providing continuous informative trends of the monitored values over variable time periods chosen because of each specific neonates degree of instability. Physiological trend screens can be viewed across crowded units for doctors and nurses to assess an unstable baby whilst at the same time performing a procedure on another baby.

Mary monitoring

Many intensive care computer applications have a bias towards the collection and presentation of laboratory and numerical physiological data [7, 8]. In Edinburgh, U.K. we use a computer system (called 'Mary') [9] which emphasises the presentation of multi channel physiological data as trend graphs. Trend graphs have been chosen because of the ease with which data can be assessed. This helps when rapid decisions have to be made [10]. Assessment of an ICU monitoring system in Aberdeen U.K. demonstrated that although doctors found the system of value, they expected better graphically presented data [11]. We have attempted to ensure easy cotside access to the trend graphs for staff previously untrained in computer use. Simple graph manipulation helps to identify developing pathology as it occurs. We believe this enables faster response times to emergency situations.

The system is based in a 16 cot supraregional neonatal intensive care unit. Each individual cot has a standard industry 16 MHz 316SX PC with screen and keyboard, connected in a circuit to a Nexos network server and then to a remote doctors terminal and printer. See Fig. 1.

Mary is a menu based system (with alternative 'hot' keys), which allows real time and previously recorded trend display of physiological data. Physiological data is taken from Hewlett Packard multichannel recorder (78834A) and Nellcor oxygen saturation monitors. Respiratory information is taken from EME Insight and Critikon Oxycheck monitors. Input to the computers is either via an A to D board or by RS232 output from the monitors.

Up to 32 channels of physiological information can be monitored. A maximum of five channels, in any combination of those currently monitored can be viewed. Paramount in the system design is ease of manipulation of the displayed physiological information. Each channel of physiological informa-

tion can be changed with regard to its value scale, time scale and its relative size and position to the other displayed graphs. Thus the components of physiological events can be viewed together in a highly flexible fashion. All these functions require the use of only two keys. An autoscaling function chooses the most appropriate scale for the displayed graphs. A cursor can identify the exact values at any chosen time.

Data can be viewed in real time either as one second information (denoted by a red time bar) where each one second value is plotted, or as one minute information (denoted by a blue time bar) where sixty one second values are averaged to produce a one minute point value. One second graphs can be viewed over a period ranging from 7 minutes to 78 minutes with 10 intervening time scales. One minute data can be viewed over a range of 7 hours up to 3 days, with 10 intervening time scales. This manipulation requires the use of only two keys. One second data is automatically stored for 72 hours during which time a request can be made to permanently save the one second data points. When monitoring in real time all other Mary functions can be performed and viewed by use of a large window whilst the last two hours of real time physiological data are displayed in a smaller window on the right of the screen. Data from any part of the infants monitored stay in the neonatal unit can be recalled. Scrolling of this recorded trend data allows an appreciation of the natural progression of events as they would appear in real time.

A popular 'user friendly' function is the ability to change the colours of the displayed graphs. Staff often change the colours of the graphs to their favourites at the beginning of their shift. Trend data may be viewed as the mean and standard deviation of the data points over each minute in one second data, or each hour in one minute data.

Data and timed comments of up to 40 characters can be entered in real time or when identified by a cursor in the recorded trend data (retrospective comments are marked by an asterisk). It is not possible to remove comments, however they may later be questioned by use of a '?' function. This records the comment in grey rather than white

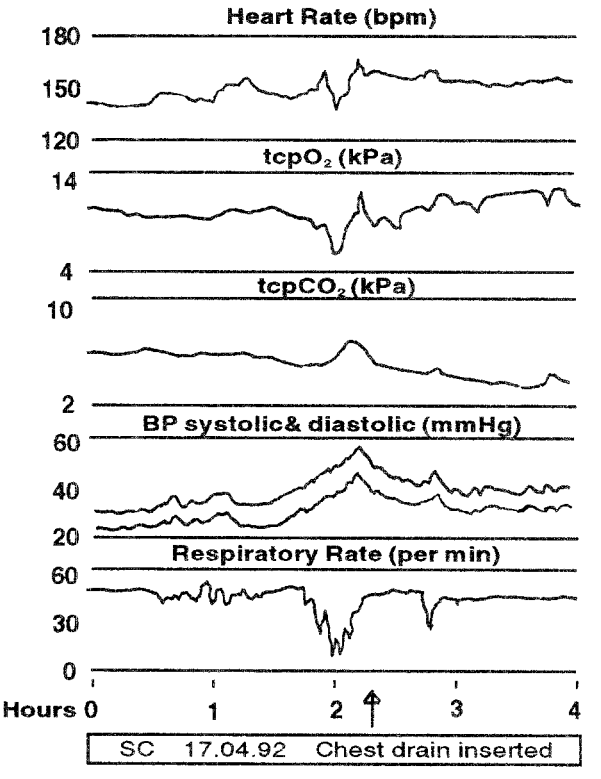

Fig. 2. Pneumothorax with comment.

indicating there is a question about the veracity of that comment. Comment identification is by voluntary entering of initials by the clinical staff. Individual comments may be viewed along the base of the screen with the appropriate graphs appearing above (see fig. 2). Alternatively a list of all comments made can be viewed.

Nurses receive initial instruction on the computer system on arrival to the unit by the computer research staff. Patient information is entered onto a patient registration form, which forms part of a comprehensive neonatal database. A statistics programme allows the analysis of collected data. Statistical results may be printed or transferred to an ASCII file for further analysis on a commercial statistical software package.

Ventilator data can be viewed as a table with automatic storage of each significant change timed and displayed. Blood gas results can be manually entered into a flow sheet and also appear on the comments page. Help screens are available to assist

at any stage. Patient recorded data can be archived to and from the hard disc of the server at any time.

Assessment of the system

New equipment should always be carefully assessed prior to its acceptance within an intensive care area. Over three years we hope to assess; (a) The short term and long term outcome of the neonates comparing randomised monitored and non monitored groups, (b) the perceived value by members of staff, (c) the perceived value by parents and (d) the accuracy of the computer record. Consideration will also be given to the reliability of the system hardware and software.

Analysis of first 98 babies, showed that neonates spend a range of 1 to 89 days (median 7) being monitored on computer. An assessment of computer usage can be inferred by the number of comments entered. An average of 22 comments per day (SD 4.84) were entered in the first seven days. Comment numbers remain consistent throughout the seven day period.

We are assessing staff and parental responses to the introduction of this new system by anonymous questionnaire, Table 1 and 2.

Discussion

Computers have common applications in both adult and neonatal intensive care areas. The nature of the neonatal patient however demands special consideration when the design requirements of a neonatal computer monitoring system are being chosen. We have attempted to address these considerations in Edinburgh with the development of a system with three particular areas of use, (1) a real time clinical tool to assist care, (2) a system to continually evaluate neonatal physiology and aid neonatal research, (3) a system that can educate staff.

Clinical real time use

We have begun to noticeably alter patient management in response to physiological trends by using one second trend data:

Apnoea and bradycardia; Staff are now able to detect developing apnoeas and bradycardias, a common neonatal problem, and using real time graphs differentiate between central and obstructive apnoea. Central apnoea is quickly followed by a bradycardia (Fig. 3), whereas obstructive apnoea will be associated with initial tachycardia followed later by hypoxic bradycardia (Fig. 4). This has lead to the correct replacement of partially blocked ET tubes.

Pneumothorax; Pneumothorax has always been regarded as causing an immediate deterioration in a neonate. The computer trend data shows identifiable trends of deterioration often one to two hours prior to the pneumothorax being clinically obvious; increasing heart rate (initially), blood

Table 1. Parent Questionnaire.

Given to all parents whose babies have been monitored by computer in the neonatal unit, 71 analysed (%).

Q1	Have you previously used a computer	Yes	87	No	13		
Q2	Was your baby being monitored by computer	Yes	85	No	15		
Q3	Could you differentiate your baby's computer from the rest of the equipment	Yes	87	No	13		
Q4	How did the computers make you feel						
	more anxious	5	no difference	43	less anxious	52	
Q5	Why do you believe the computer was there						
	for baby's benefit	40	for research	7	for both	53	
Q6	How do you feel about your baby being monitored by computer						
	pleased	43	not worried if it helps	57	worried	0	

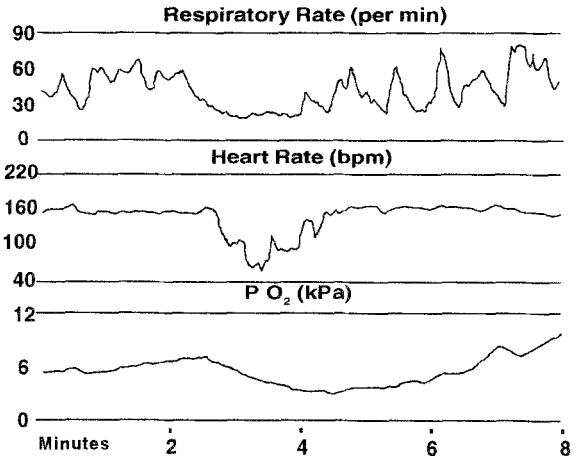

Fig. 3. Central Apnoea.

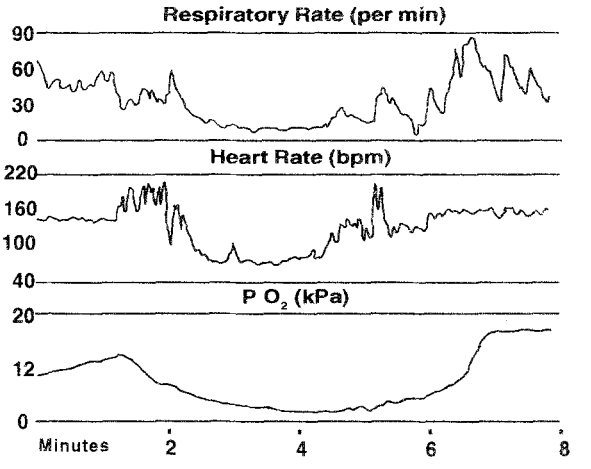

Fig. 4. Obstructive Apnoea.

pressure and tcpCO2 with falling tcpO2 and an erratic respiratory rate (Fig. 2). As pneumothorax is probably a major precipitant of intraventricular haemorrhage in early neonatal life, early identification may have significant effects on the long term outcome of these neonates.

Neonatal distress; A distressed infant has an increased variability of heart rate, respiratory rate and transcutaneous oxygen [12]. Real time trend display of the standard deviation of heart rate and respiratory rate gives a valuable indication of the distress associated with procedures e.g. extubation, and therefore how well the infant is coping.

Neonatal physiological research

Computer monitoring is an invaluable aid in the assessment of the effects of treatments and procedures on the neonate. The effects of handling procedures on transcutaneous carbon dioxide have been demonstrated [13]. TcpCO2 changed more significantly during ET suction than with four other procedures. We are currently assessing different methods of ET suction to minimise the effect of this procedure on the neonate.

Previously undescribed cyclical variation of blood pressure in severely ill neonates have been demonstrated using this network [14]. The effects of these hypertensive blood pressure waves on the pressure passive neonatal cerebral circulation are being investigated.

Trend recorded data as a teaching aid

Recorded data print outs are used to teach both medical and nursing staff the physiological basis of

Table 2. Staff questionnaire.

Given to all members of staff after 6 months computer usage. 62 questionnaires assessed, following replies received (%).									
Q1	Have you previously used a computer				Yes	65		No	35
Q2	For managing the baby, is the computer								
	No help	8	Little help	20	Moderate help	50		Very helpful	22
Q3	How many months was it before you felt familiar with the computers								
	1–2 months	30	3–4 months	30	5–6 months	5		still unfamiliar	25
Q4	Do you feel hassled into using the computer				Yes	10		No	90
Q5	How much has the computer affected your understanding of neonatal physiology								
	Increased it	51	No change	49	Confused me	0			
Q6	Does the computer come up to your expectations				Yes	92		No	8

neonatal intensive care and the patterns of physiology associated with frequent deteriorations. We are increasing staff awareness of the stress of handling on the neonate. The discussion of neonatal deteriorations can be aided by re-appraisal of the physiological changes that occurred both acutely at the time and in the periods prior to the event.

Staff acceptance of the computer system assessed by responses to an anonymous questionnaire have been favourable (Table 2); as in other centres acceptance by doctors has been slower than nurses, but we are beginning to see developing interest. The ability to change graph colours is appealing and this simple introduction to the computer software increases awareness of the system and reduces apprehension. Fear that the system will detract from patient care does not seem to be born out by our initial observations. The ability of the nurses to scroll back through the data and place retrospective comments enables them to use the data in real time to anticipate problems and if busy go back later to describe their actions at that time.

Although our patients can express no opinion on their care, it is important that their parents accept and acknowledge the value of the computer system for the care of their baby. Parent questionnaires show a satisfactory response (Table 1). The consequences of neonatal care on the developing relationship between parents and their child can be quite damaging in the long term [15] and it is important that we are aware of this when increasing the 'intensity' of that care.

Neonatal intensive care can benefit from computer assisted data presentation. We believe it is the flexibility of this system in the manipulation of the graphed data that delineates its success in acute care situations. Other systems have not easily been applied to neonatal care as they have not had the same degree of flexibility [16, 17]. Whilst it is true that most intensive care computer programmes only gain acceptability in the unit in which they are developed [18], 'Mary' has already superseded this by successfully being used as a network in four other UK regional neonatal units.

Neonatal computer systems may well be less developed than adult counterparts, but we believe they are beginning to catch up.

References

1. Gardner RM, Sittig DF, Budd MC. Computers in the Intensive Care Unit: Match or mismatch in: Shoemaker WC, editor. Textbook of critical care. Philadelphia: Saunder, 1989: 240–59.
2. Pryor TA. Computerised nurse charting. Int J Clin Mon Comp 1989; 6: 173–9.
3. Sivek ED, Gochberg JS, Fronek R, Scott D. Lessons to be learned from the design, development and implementation of a computerised patient care management system for the Intensive Care Unit. Symp Comput Applic Med Care 1987; 11: 614–9.
4. Colvin JR, Kenny GNC. Computerised management of Intensive Care Unit data. In: Coleridge Smith PD, Scurr JH, editors. Medical applications of microcomputers. London: Springer Verlag, 1988: 51–9.
5. Mok Q, Bass CA, Ducker DA, McIntosh N. Temperature instability during nursing procedures in preterm neonates. Arch Dis Child 1991; 66: 783–6.
6. Murdoch DR, Darlow BA. Handling during neonatal intensive care. Arch Dis Child 1984; 59: 957–61.
7. Ross DG, Ramayya P, Kulkami V. ABICUS: Aberdeen Intensive Care Unit System. Int J Clin Mon Comp 1990; 7: 69–81.
8. Avila LS, Shabot M. Keys to the successful implementation of an ICU patient data management system. Int J Clin Mon Comp 1988; 5: 15–25.
9. McIntosh N, Ducker DA, Bass CA. Mary – A computerised neonatal cot monitoring system. Int Ther Clin Mon 1989 Nov: 272–82.
10. Shabot MM, Carlton PD, Sadoff S, Nolan-Avila L. Graphical reports and displays for complex ICU data: a new, flexible and configurable method. Comp Meth Prog Biomed 1986; 22: 111–6.
11. Gilhooly KJ, Logie R, Ross D, Ramayya P, Green C. Users' perceptions of a computerised information system in intensive care (ABICUS) on introduction and after 2 months use. Int J Clin Mon Comp 1991; 8: 101–6.
12. McIntosh N, van Veen L, Bramayer H. The pain of heel prick and its alleviation in the preterm infant. Pain 1991. Submitted.
13. Deere S, Cunningham S, Bass C, McIntosh N. Episodes of hypercapnia during routine procedures in preterm infants. In: Lafeber HN, editor. Fetal and Neonatal Physiological Measurements. Amsterdam: Elsevier Science Publishers BV, 1991: 195–7.
14. Cunningham S, Deere S, Bass C, Badger PA, McIntosh N. Cyclical variation of blood pressure and heart rate in intensive care neonates. Early Hum Dev. In press.
15. Jeffcoate JA, Humphrey ME, Lloyd JK. Disturbance in Parent-child Relationship following Preterm Delivery. Dev Med Child Neurol 1979; 21: 344–52.
16. Kari A, Ruokonen E, Takala J. Comparison of acceptance and performance of automated and manual data manage-

ment systems in intensive care. Int J Clin Mon Comp 1990; 7: 157–62.
17. Van der Weil AR. Multichannel recording and analysis of physiological data using a personal computer. Adv Exp Med Biol 1987; 220: 305–9.
18. Gardner RM, Shabot MM. Computerised ICU management: pitfalls and promises. Int J Clin Mon Comp 1990; 7: 99–105.

Address for offprints:
S. Cunningham, Neonatal Unit,
Simpson Memorial Maternity Pavilion,
Lauriston Place, Edinburgh, EH3 9EF, UK