A Review of Current Methods of Monitoring in Neonatal Intensive Care

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SUMMARY: Neonatal intensive care requires continuous close monitoring of several physiological parameters. The machinery involved is complex but has to be understood by medical staff with the minimum of training in its use. Failure of correct application and interpretation of results can be dangerous for the sick or preterm infant.

The current status of monitors in the neonatal intensive care unit is reviewed.

Introduction

The neonatal period is the first 28 days of life and has the highest mortality of any time. Problems causing permanent damage to an individual are also common, the most significant risk being to the premature and sick infants who require special or intensive care.

Recent advances in neonatal care have resulted in an increasing number of these infants, who are usually potentially normal at birth, surviving, with a low incidence of significant handicap. A comparison of infants admitted to a specialist unit with those declined admission has shown the marked improvement in the survival of the former group.²

There have been major advances in the understanding of the pathophysiology of neonatal problems and in the ability to safely ventilate and feed these babies. However, sick low birth weight infants deteriorate following even minor manipulations,³ and one must endeavour to obtain as much information as possible, with the minimum of handling, after initial application of monitors.

This paper will review the current role of monitors in modern neonatal intensive care and discuss the needs of special care units in British Military Hospitals.

Temperature Monitoring

The relatively large surface area to bodyweight ratio, and the immaturity of thermal control mechanisms make the newborn particularly susceptible to thermal stress. Premature babies have a lower mortality⁴ if they are kept warm and modern incubators and overhead heaters are designed to keep the infant in a stable thermal environment.

There is a wide range of 'normal' rectal temperatures recorded in babies judged to be in an appropriate thermal environment, and the rectal recording is markedly influenced by depth of insertion of the thermometer or probe.⁵

Rectal temperature alone cannot be used as a guide to whether a baby is in the most appropriate thermal environment. It gives no information on how stressed the baby is in maintaining a normal rectal temperature. The knowledge of a core temperature and its difference from

a peripheral temperature allows more physiological deductions to be made. A core temperature more than 1-2°C in excess of the peripheral temperature implies inadequate skin perfusion which may be the result of environmental cold stress or hypovolaemia, with a failure to perfuse the skin. These changes in the hypovolaemic baby occur before changes in blood pressure or heart rate. A peripheral temperature in excess of the core temperature implies an environmental heat stress.

Thermistors attached to the skin continuously monitor temperature. The temperature of the skin over the deltoid follows the rectal temperature closely and can be used as an indicator of core temperature. A probe attached to a foot or hand will measure peripheral temperature. Modern monitors can measure and display both temperatures simultaneously.

Simple temperature recordings remain one of the most useful and efficient monitoring objectives in neonatal intensive care.

Respiration and ECG Monitoring

Apnoea is a common problem in preterm and sick infants. Repeated apnoea can be due to a number of insults, e.g. infection or birth asphyxia, but premature infants frequently have apnoeic spells related only to their immaturity. These episodes cannot be anticipated because of their irregular occurrence and, if undiagnosed, can cause central nervous system damage.

There are several systems in use to monitor respiration and detect apnoea.

The apnoea mattress⁶ consists of an air-filled, segmented mattress placed under the baby. Breathing movements cause air flow from one segment to another, this flow being detected by a transducer. This is still a commonly used device although there are many false positive and negative alarms⁷. One major problem is making sure the mattress remains inflated with air.

ECG leads attached to the side of the chest can double as a respiration monitor (Figure 1). Changes in impedance with chest wall movement can be used to produce a respiration trace and breathing rate. This method is very susceptible to movement of the baby.

Fig. 1 ECG electrodes on chest doubling as respiratory monitor.

The impedance mattress pad (Figure 2) is a widely used system and is very sensitive, although the baby may wriggle off the small mattress resulting in false apnoea. If the baby is incorrectly positioned, the pad is so sensitive that it can detect heart rate in addition to respiration rate, thus failing to alarm despite quite long periods of apnoea.

Fig. 2 Impedance mattress pad and monitor.
(N H Eastwood & Son Ltd., London)

A recent development is an alarm consisting of a small pneumatic sensor capsule (Pye Dynamic Ltd, Bushey, UK), taped to the baby's abdomen, which is sensitive to changes in the curvature of the abdominal wall and thus responds to each respiratory movement but not to general movement of the limbs (Figure 3).

All apnoea alarms and respiratory monitors have problems, particularly those due to movement of the baby. Apnoeic spells usually have associated bradycardia and it is essential in the high dependency or intensive care unit to monitor heart rate and respiratory rate concurrently.

Fig. 3 Pye dynamic respiration monitor

The alarm system on ECG monitors in the neonatal unit are usually geared to detect changes in heart rate as other arrhythmias are uncommon.

Rate meters function by summing the complexes with the maximum deflection from the base line. In the neonate the T wave is often as large as the QRS complex and the heart rate recorded can be twice the actual rate. An oscilloscope is therefore essential. This will also help detect abnormalities in heart rate artificially produced by the movements of the baby.

The addition of sound to the QRS complexes is essential especially in a busy unit when changes in rate are heard long before they are seen on the oscilloscope or rate meter. Overall, ECG monitors are widely accepted as crucial in neonatal intensive care.

Inspired Oxygen Monitoring

Uncontrolled oxygen therapy has been implicated as the cause of retrolental fibroplasia leading to blindness. It is therefore essential to monitor oxygen in the inspired gas of the preterm infant. There are a number of electrochemical sensors working on a Clark electrode principle (Figure 4).

Fig. 4 Inspired oxygen monitor and electrode

These sensors can be used in a headbox, incubator or ventilator circuit and give little trouble as long as they are calibrated daily in air and in 100% oxygen.

Blood Pressure Monitoring

Sick, preterm infants are often hypotensive. The aetiology of this low blood pressure is multifactorial but includes hypovolaemia, hypoxia, septicaemia, hypoglycaemia, hypocalcaemia and possible myocardial damage^{10,11}. A low blood pressure is associated with an increased mortality and therefore monitoring of blood pressure is an essential part of intensive care.

Transducers attached to arterial lines, usually umbilical or radial, give accurate readings whilst these catheters function.

Non invasive blood pressure recording is possible using the Doppler flowmeter but this is not continuous and the baby is disturbed for each reading. Oscillometric techniques allow continuous, non invasive monitoring in all neonates (Fig 5). The cuff is automatically inflated and during deflation the small oscillations in the cuff induced by blood flowing back through the artery are used to detect systolic, diastolic and mean pressures. These readings correlate well with direct arterial pressures if the correct size cuffs are properly attached to the baby's arm or leg^{12,13}.

Fig. 5 Non-invasive blood pressure monitor

Continuous Intravascular Oxygen Monitoring

A major advance in neonatal intensive care has been the introduction of continuously recording PaO_2 catheters¹⁴. A double lumen catheter (Figures 6 and 7) (D G Searle & Co) is passed into the abdominal aorta through one of the umbilical arteries (Figure 8). The tip of the catheter consists of a Ag/AgCl electrode, the wires running from this through one lumen of the catheter to the recorder (Figure 9). The other lumen has a side hole opening at the tip and is used for infusions, arterial blood sampling, and for continuous blood pressure monitoring. Once calibrated, the electrode remains accurate for several days¹⁵.

Fig. 6. Searle intra-arterial oxygen electrode

Fig. 7 Tip of Searle catheter showing electrode and side hole lumen

Fig. 8 Intra-arterial catheter in abdominal aorta

Fig. 9 PO₂ monitor for Searle intra-arterial catheter

Continuous oxygen monitoring has improved control of oxygenation and has provided other useful information. The normal, apparently stable, neonate with respiratory problems exhibits surprisingly large swings in PaO₂; intermittent sampling at the trough or peak of one of these swings can obviously give a very different impression of the infant's oxygenation. The deleterious effects of any form of physical handling on these infants have also been highlighted. Virtually all procedures cause serious falls in oxygenation and the more serious insult of peripheral arterial puncture can cause marked and prolonged hypoxaemia.

These catheters allow samples to be taken, without handling the baby, for routine blood tests and repeated estimations of PaCO₂ and pH which, like PaO₂, need close monitoring in these sick infants.

The intravascular electrodes are not without their complications¹⁶ but despite these they represent one of the major advances in neonatal care in recent years.

Transcutaneous Oxygen Monitoring

With these monitors, PaO₂ is measured by an electrode attached to the skin (Fig 10). This contains a heater, set at 44°C, which increases the blood supply to the skin under the electrode. A Ag/AgCl electrode then measures oxygen by diffusion through the skin. In well perfused infants, within the normal PaO₂ range, the electrode responds rapidly to changes in PaO₂ measured simultaneously with an intra-aortic catheter¹⁷. When perfusion is poor, as in the hypotensive child or when the electrode is sited over bone, the device seriously underestimates PaO₂. The nursing time to keep them working correctly is large¹⁸ as there are often air leaks under the electrode, and there is a need to resite and recalibrate it every four hours.

Personal experience with a transcutaneous monitor linked to a computer monitoring system has shown that in many babies the monitor is not reading correctly or is not attached to the baby for up to 50% of the time. The cost of

maintenance was estimated in 1981 as £1500 — £2000 a year¹⁸. It is also wrong to use a transcutaneous monitor without at least one daily blood gas for calibration and in the acute phase of any illness more gases will be needed to monitor PCO₂ and pH.

In experienced hands, the use of these monitors in both RDS and apnoea is established but they are no substitute for an indwelling arterial line in the acute phase of any neonatal respiratory disease.

Transcutaneous carbon dioxide monitors are now commercially available. Measurements of CO₂ are important in the care of ill neonates and these are usually obtained from arterial or capillary samples. Carbon dioxide tends to alter more slowly than PaO₂ and it is possible to monitor this parameter with repeated sampling.

Continuous CO₂ monitors will decrease the number of samples but at present these electrodes require considerable calibration and the same nursing problems apply as for transcutaneous PO₂ monitors.

Intracranial Pressure Monitoring

Changes in intracranial pressure can be monitored using a sensor fixed to the anterior fontanelle (M1000 Laidlaw intracranial pressure monitor — Specialised Laboratory Equipment, Croydon UK). This can be useful after birth asphyxia or intracerebral haemorrhage, as estimation of intracranial pressure by palpation of the anterior fontanelle is difficult in all but extreme cases. Fixing the sensor is a problem, but once secure, the monitor is very sensitive to pressure changes¹⁹.

Trend Recording

The ability to analyse data by recording continuously the monitor readings onto paper, trend recorder or computer leads to a better understanding of the inter-relationship of certain parameters in the newborn. Hopefully by looking at the trends one may be able to predict future events and take suitable avoiding action.

Fig. 10 Transcutaneous PO₂ electrode and monitor

Discussion

New methods of monitoring have helped improve standards of neonatal care. However, the incorrect application of complex machinery can make life more dangerous for the sick, preterm infant. Only by understanding why the measurements are being made and the way in which the monitor obtains the readings, can the observer appreciate which abnormal results are due to problems with the baby rather than machine error, the latter being common. All monitors require a large amount of nursing time to keep them operating correctly.

In military hospitals, the throughput of babies is small and the staff turnover high. It is therefore vital that the expensive intricate equipment in special care units is standardised. Only in this way will staff become sufficiently familiar with the equipment to allow its safe and proper use in the care of sick infants.

There is no doubt that small babies do better if transferred to a specialist neonatal intensive care centre^{1,2}. However, this is not always possible because of limited space in these units. The Army has an additional responsibility in BAOR and Hong Kong where transfer to specialist units is more difficult. Cultural differences in the approach to parents and parent-infant bonding have, in personal experience in BAOR, created significant problems. It is essential that future planning for military hospitals outside UK includes a policy to care for sick neonates, possibly in a central referral centre.

With current delivery rates (annual reports 1979-1982), the military hospitals with paediatric units should have a minimum of one intensive care cot and three special care cots. The former need most of the monitoring equipment described above, as well as facilities for ventilation, at least in the short term. The latter require the ability to monitor ECG, respiration, inspired O₂, transcutaneous PO₂, and blood pressure.

The recommendations of the Short report^{2,9} concerning nursing and medical staff for neonatal units need to be considered. In particular, neonatal intensive care needs to be recognised by the Army Nursing Services as a speciality in its own right and not as a part of general midwifery.

This paper has reviewed the current state of monitoring sick neonates. The equipment has helped to ensure that most of these babies survive intact. There is an increasing need for a certain level of neonatal expertise in military hospitals and, in particular, this will require more trained nursing staff familiar with standardised equipment.

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