

## The effect of introduction of minimal standards of neonatal care on in-hospital mortality

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### SUMMARY

A retrospective study was done to assess the effect on in-hospital neonatal mortality of a series of interventions in neonatal care in the highlands of Papua New Guinea. Between 1995 and 1997, prior to the interventions, the mortality among neonates admitted to the Goroka Hospital Special Care Nursery was 18% and two-thirds of very low birthweight (1-1.5 kg) neonates died. The interventions began in December 1997 and were aimed at reducing mortality among all neonates and particularly among those with very low birthweight. Compared to the 30-month period prior to the interventions, the in-hospital neonatal mortality in the 30-month period after the interventions began was 44% lower (relative risk (RR) 0.56, 95% confidence interval (CI) 0.45-0.69). After adjustment for a higher number of neonates <1500 g in the pre-intervention period, the relative risk was 0.59 (0.48-0.74). The mortality in the intervention phase for very low birthweight babies was 56% lower (RR 0.44, 95% CI 0.30-0.65) and for moderate low birthweight (1.5-2 kg) 50% lower (RR 0.50, 95% CI 0.28-0.90). Mortality was also significantly lower in the intervention phase in neonates with a diagnosis of septicaemia or pneumonia (RR 0.36, 95% CI 0.19-0.67), but there were no differences in mortality from birth asphyxia, meconium aspiration or extremely low birthweight (<1 kg). We estimate that in the 30 months after beginning the interventions 82 neonatal deaths that would previously have occurred were avoided. The costs of the improvements in technology described are estimated at US\$445 (K1000) per life saved, but substantial training and improved supervision of staff and other human factors may have been more important than equipment. Apnoea monitors were the single most important technology introduced. A similar evaluation of the effect of minimal standards should be done without the use of incubators and overhead heaters, as these are costly and may be dangerous when used by less experienced operators. The 33 neonatal deaths that we estimate were avoided each year because of the interventions represent less than 10% of all neonatal deaths in the province. Although this study provides justification for increasing the technology for supportive neonatal care and training in medium-sized hospitals in rural areas in developing countries, estimates of cost-effectiveness must be compared with other interventions that will effectively lower neonatal mortality, both in and out of hospitals.

### Introduction

In developing countries about one-quarter to one-third of all child deaths occur in the first 28 days of life. Worldwide 2.4 million deaths occur annually from perinatal conditions; 96.5% of these deaths occur in developing countries (1). This makes the neonatal period the most hazardous time of life. In Papua New Guinea (PNG) there are at least 6000 neonatal deaths each year. The most common causes of

neonatal death in PNG and in other developing countries are low birthweight, which includes prematurity and intrauterine growth restriction, bacterial infections, birth asphyxia and congenital abnormalities. Although most neonatal deaths occur outside hospitals, the in-hospital neonatal mortality in PNG is very high.

In the period 1995-1997 mortality among neonates admitted to the Special Care Nursery

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at Goroka Hospital was 18%. The neonatal mortality was more than twice the mortality of older children admitted to the hospital and seemed excessive. Two-thirds of very low birthweight (1-1.5 kg) babies died. From the start of 1998 deliberate changes were made to neonatal practice. The changes were in line with the recently developed Minimal Standards of Neonatal Care that are published as a Policy Statement of the Paediatric Society of PNG in this edition of the Journal. This study was done to determine whether the introduction of Minimal Standards of Neonatal Care has resulted in a significant reduction in mortality. This paper briefly outlines previous neonatal practice at Goroka, the new principles adopted and the practical changes that were made, and describes the effect of the interventions on weight- and diagnosis-specific neonatal mortality.

### Neonatal care before 1998

Until the end of 1997 neonatal care was not based on protocols for specific conditions. Sick neonates were admitted to a small room that had predominantly artificial lighting, apart from a few small windows close to the ceiling on one wall. The room was poorly ventilated and had a fan-forced heater to maintain the room temperature at 28-30°C. All neonates were nursed in open aluminium cots. Piped oxygen was available to most cots and administration of supplemental oxygen was based on clinical signs (predominantly central cyanosis). The tubing on the suction apparatus was not routinely changed or cleaned and a thick deposit of mould had built up inside it. Low birthweight neonates and other critically ill babies were wrapped in blankets for extra warmth and comfort. Apart from intermittent nursing observation, which is difficult in a partly swaddled baby, there was no way of monitoring for apnoea. Aminophylline was not routinely given to premature babies. Low birthweight babies were often fed full-volume feeds (60 ml/kg/day) by nasogastric tube from the time of admission and because few mothers had a good supply of milk on day 1, this was often supplemented by powdered cow's milk with added sugar: so-called 'sugar-milk'. Standard treatment rarely included antibiotics active against *Staphylococcus aureus*. Intravenous fluids were given, but there was no

standardization of equipment. Often adult intravenous giving sets were used, with the risk of fatal overhydration in small babies. No nurses were trained in neonatal care. Apart from data recorded in the neonatal admissions book (admissions, diagnoses, weight, discharges, deaths, absconders) there was no audit of clinical practice, or of perinatal or neonatal mortality.

### Neonatal care from 1998

In December 1997 changes to neonatal care were introduced. The Neonatal Unit moved to a larger room with natural lighting. Two old infant incubators, which had been donated some years before, were found in a storeroom, cleaned up and used to nurse low birthweight babies who were in stable conditions. Two new donated infant warmers (open resuscitation cots with overhead heaters and oxygen) were used for the most critically ill babies. Thus, at any one time, we could nurse 4 critically ill or low birthweight babies naked for closer observation. Two neonatal apnoea monitors were bought (Respiratory Monitor MR10, Graseby Medical, EBOS New Zealand).

We were particularly committed to reducing the mortality from babies weighing 1000-1500 g, of whom two-thirds had previously died. We thought that many of these very low birthweight babies should survive with improved supportive care. A protocol for treatment of low birthweight babies was devised (see Appendix). Training of nurses in specific neonatal problems and increased clinical supervision occurred. Pulse oximetry was introduced in March 1998 and a protocol for administration of oxygen was devised. A weekly mortality audit, in which all neonatal and child deaths were discussed, began in March 1998.

Changes in neonatal clinical practice were based on the following 10 principles.

- 1 Supplemental oxygen administration based on objective evidence of hypoxaemia  
Because clinical signs predicting hypoxaemia in neonates are relatively insensitive, use of protocols for supplemental oxygen administration based

on monitoring of pulse oximetry may be a way to ration an expensive and often scarce resource, ensuring that oxygen is given to those who will benefit most. Oxygen was given to all neonates with cutaneous oxygen saturation (SpO<sub>2</sub>) of 85% or less.

## 2 Detecting and treating apnoea

We thought that unrecognized apnoea had been a major cause of neonatal mortality among premature neonates and also among babies with sepsis and birth asphyxia in the pre-intervention phase. The use of apnoea monitors, aminophylline (for premature neonates) and close observation of all very sick babies nursed naked under a radiant heat source were key strategies.

## 3 Maintaining a stable temperature within the normal range

## 4 Preventing, detecting and treating hypoglycaemia

Hypoglycaemia complicates many neonatal conditions, particularly low birthweight and sepsis. It occurs because of insufficient glycogen stores in the liver, inability to feed (which has multiple causes) and increased glucose metabolism during illness. Hypoglycaemia increases the risk of dying from any given condition (2). The clinical signs are nonspecific and regular blood glucose monitoring of critically ill neonates is required. Careful correction of hypoglycaemia using intravenous glucose or enteral feeding is essential.

## 5 Ward organization to ensure close observation of the most critically ill babies

## 6 Safe use of intravenous fluids in selected critically ill neonates

In very low birthweight neonates large-volume enteral feeding in the first day or two of life is rarely well tolerated and may increase the risk of necrotizing enterocolitis, as does the use of any artificial formula feeding. For babies under 1.5 kg we thought that slow increases in enteral feeding volumes using *only* expressed breastmilk would be best coupled with intravenous fluids to maintain

hydration and prevent hypoglycaemia in the first few days of life. Other critically ill neonates need to have intravenous fluid as resuscitation, or in the first days while the illness is stabilizing. The risks of intravenous fluids are overhydration and IV cannula site complications. These can be fatal, so a major effort was made to deliver IV fluids safely.

## 7 Evidence-based use of antibiotics

Although many seriously ill neonates have bacterial infections, the inappropriate use of broad-spectrum antibiotics will lead to colonization of babies, and of neonatal units, with bacteria that are resistant to standard antibiotics. *Staphylococcus aureus* has been shown to be a common cause of infection in young infants in Goroka (3), and resistant enteric gram-negative bacilli are a common cause of neonatal death (4). We began using flucloxacillin for severely ill neonates who had very severe pneumonia or generalized septicemia and who had coexistent risk factors for staphylococcal infection, including purulent umbilical cord, skin pustules and purulent conjunctivitis. In these babies flucloxacillin was combined with daily-dose gentamicin (5). For systemic sepsis of moderate severity benzylpenicillin and gentamicin remained the standard treatment.

## 8 Prevention of nosocomial sepsis

Nosocomial sepsis may occur in up to 20% of in-hospital neonatal deaths. Strict handwashing and other basic infection control measures were emphasized.

## 9 Auditing of practice

It is only by keeping accurate records of all admissions and outcomes that patterns of adverse events will become evident. Clinical audit is essential for training and quality assurance and we thought it should be an integral part of efforts to reduce neonatal mortality. A weekly audit meeting where all child deaths were reviewed began in 1998.

## 10 Training of nurses in neonatal high-dependency care.

## Methods

To estimate the effects of these changes a review was done using the Neonatal Unit admission book of all admissions and deaths for the 30 months prior to the changes in neonatal care (July 1995-December 1997) and 30 months after (January 1998-June 2000). The information is collected routinely by the sister-in-charge of the Neonatal Unit and summarized every month. Data extracted were the total number of admissions, total deaths, admissions and deaths specific for weights <1000 g, 1000-1499 g, 1500-1999 g and admissions and deaths specific for the following four diagnoses: septicaemia, pneumonia, birth asphyxia and meconium aspiration. Data were entered into Excel and analyzed using Stata 5.0. Relative risks (and 95% confidence intervals) for mortality during the second 30-month study period (intervention phase) compared with the first 30 months (pre-intervention phase) were calculated for the key weight-specific groups and the diagnosis-specific groups. Adjustment was made for the higher number of babies weighing <1.5 kg in the pre-intervention phase.

Data quality was assessed by a comparison of the Neonatal Unit admissions book data with a parallel prospective audit conducted for the two-year period 1 April 1998 to 30 March 2000, in which one person (TD) recorded every death in children seen at Goroka Hospital.

## Results

The mortality results are summarized in Table 1. Neonatal mortality was 44% lower in the intervention period (relative risk 0.56, 95% confidence interval 0.45-0.69). After adjustment for the higher number of neonates weighing <1.5 kg in the pre-intervention phase the neonatal mortality was 41% lower (relative risk 0.59, 95% confidence interval 0.48-0.74). In the intervention phase lower mortality occurred in all weight groups and the key diagnosis-specific groups. The largest reductions in mortality were in very low birthweight (VLBW) babies (1000 g to 1499 g) in whom the relative risk was 0.44 (95% CI 0.30-0.65) after the institution of the changes described, including the specific protocol for management.

We combined the diagnostic categories septicaemia and pneumonia in the analysis (Table 1), as there is substantial overlap in classifying these two infections in neonates. In the first 30 months there were 311 recorded cases of septicaemia but only 30 cases of pneumonia and in the second 30 months there were only 112 cases of septicaemia but 112 cases of pneumonia. The diagnosis-specific mortality for the separate classification of septicaemia was lower in the intervention phase (13.2% to 7.1%) but not significantly different from before the interventions (RR 0.57, 95% CI 0.28-1.19). The mortality from pneumonia was substantially lower (20% to 2.7%) in the intervention period (RR 0.16, 95% CI 0.04-0.59) but the numbers were small and diagnostic consistency over time is not certain.

Similarly for the analysis we combined the diagnoses birth asphyxia and meconium aspiration (Table 1). Both are part of the birth asphyxia syndrome and there was substantial overlap in data recording. There was no significant change in mortality from these conditions during the intervention phase. Without combining these two diagnoses the relative risks for mortality from babies classified as having birth asphyxia was 0.65 (0.36-1.20) and for meconium aspiration was 0.48 (0.11-2.06).

There was no significant difference in mortality risk in the intervention phase for babies with extremely low birthweight (ELBW) (<1 kg). About three-quarters of these babies still die.

Based on the pre-intervention data, after adjustment for the higher number of VLBW and ELBW babies in the pre-intervention phase, the expected number of neonatal deaths in the 30-month intervention phase was 204 ( $0.163 \times 1247 = 204$ ). The difference between the expected and observed number of neonatal deaths in the intervention phase was 82 (95% CI 67-102). Therefore, the number of neonatal deaths avoided annually from these interventions was 33 (95% CI 27-41).

The cost-effectiveness of the additional technology required for the interventions can be approximately quantified. The costs are as follows: 2 infant warmers US\$15,000; 2 basic

**TABLE 1**

MORTALITY WITHIN KEY WEIGHT AND DIAGNOSIS CATEGORIES AND RELATIVE RISK OF MORTALITY IN THE INTERVENTION PERIOD COMPARED WITH THE PRE-INTERVENTION PERIOD

	Admissions	Deaths	Mortality (%)	Relative risk (95% CI) after changes	Fisher's exact test p value
<b>Total admissions</b>					
Jul 1995-Dec 1997	1167	205	17.6		
Jan 1998-Jun 2000	1247	122	9.8	0.56 (0.45-0.69)	<0.0001
RR adjusted for higher number of VLBW and ELBW neonates in 1995-1997				0.59 (0.48-0.74)	<0.0001
<b>Birthweight &lt;1000 g</b>					
Jul 1995-Dec 1997	17	15	88.2		
Jan 1998-Jun 2000	10	7	70.0	0.79 (0.51-1.23)	0.32
<b>Birthweight 1000-1499 g</b>					
Jul 1995-Dec 1997	90	60	66.7		
Jan 1998-Jun 2000	71	21	29.6	0.44 (0.30-0.65)	<0.0001
<b>Birthweight 1500-2000 g</b>					
Jul 1995-Dec 1997	134	31	23.1		
Jan 1998-Jun 2000	120	14	11.7	0.50 (0.28-0.90)	0.02
<b>Septicaemia or pneumonia</b>					
Jul 1995-Dec 1997	341	47	13.8		
Jan 1998-Jun 2000	224	11	4.9	0.36 (0.19-0.67)	0.0006
<b>Birth asphyxia or meconium aspiration</b>					
Jul 1995-Dec 1997	135	30	22.2		
Jan 1998-Jun 2000	137	18	13.1	0.59 (0.35-1.01)	0.057

CI = confidence interval

RR = relative risk

VLBW = very low birthweight

ELBW = extremely low birthweight

neonatal incubators US\$12,000; 1 pulse oximeter US\$2000; 2 apnoea monitors US\$2500. Most other costs were being incurred with the style of neonatal care in the pre-intervention phase; but a significant cost of setting up a Unit would be 8 oxygen flow meters and humidifiers: US\$5000. Therefore, the approximate cost of the technology if one were to set up a Neonatal Unit from nothing would be US\$36,500. The estimated cost per

additional life saved over just 30 months is therefore US\$445 (36,500/82=445) or about K1000.

In terms of data quality the completeness of the admission book is a potential problem. To address this question we did a separate prospective audit of all deaths seen in the Paediatric Department (Children's Ward and Neonatal Unit) of Goroka Hospital between 1

April 1998 and 31 March 2000. During this time in the official Neonatal Unit admission book 99 deaths were recorded, but the independent audit recorded 108. Therefore, deaths in the Neonatal Unit admission book were underestimated by 9%.

### Discussion

This was not a randomized comparison of two methods of neonatal care, but a retrospective evaluation of the effects of a series of changes in case-management and clinical organization. The introduction of new technology and changes in clinical practice occurred over a period of 2-3 months, beginning in December 1997. Training in neonatal care has progressed gradually over the following 3 years. Because several changes in practice occurred it is not possible to quantify the effectiveness of any individual intervention. Rather these data can only be used to assess the effectiveness of the package of neonatal care.

A study similar to ours, but from a tertiary hospital in Nigeria where a series of general improvements in obstetric and neonatal care were introduced, showed a reduction in mortality among babies >2.5 kg, but no change in mortality for neonates of lower birthweight (6). These interventions focused on better consultation between obstetric and paediatric staff about high-risk deliveries, improvement in resuscitation skills, intravenous fluid and oxygen administration, prevention of hypoglycaemia and use of cloxacillin and gentamicin instead of penicillin and kanamycin for sepsis.

As in other developing countries (7), many of the in-hospital neonatal deaths in Goroka occur in babies born outside hospital (49 of 126, of which 42 were village births, in the independent two-year audit). Almost all the low birthweight babies seen at Goroka have a combination of intrauterine growth restriction and prematurity, and severe respiratory distress syndrome due to hyaline membrane disease is uncommon. The most common presentations and deaths are in babies born in villages to mothers who have not received antenatal care. The typical sick neonate is severely underweight and it may have taken several

days for the baby to be brought to hospital, or referred from a local health centre or aid post. They may present because they are not feeding; this is often due to the combination of immaturity, hypoxaemia, hypothermia and sepsis.

With improvements in supportive care we were able to substantially lower mortality from low birthweight in babies 1-2 kg. We were not able to significantly reduce mortality for babies with birthweight less than 1 kg. When we designed the changes to neonatal care we did not think that many of these extremely low birthweight babies were viable given the limited resources that were available. We chose to focus particularly on babies 1-1.5 kg, as two-thirds of them had previously died. To reduce mortality substantially in babies under 1 kg requires a much higher level of technology, including mechanical ventilation. This will come at a much greater cost, would benefit very few and would be a distraction from more basic and more effective interventions. A study from Pakistan of 200 infants with respiratory distress syndrome in which mechanical ventilation was required by 79% had an overall early mortality of 39% and the cost per survivor was estimated at US\$1391 (about K3100) (8). We do not think that neonatal intensive care will be appropriate for anywhere in PNG until substantial improvements occur to community maternal and neonatal health services and until all provinces can reduce neonatal mortality by means similar to what we have described, or by other interventions. What we instituted was a high level of basic supportive care for severely ill neonates, but did not include mechanical ventilation or inotropic support.

Unlike in the study from Nigeria (6) we were not able to show a significant reduction in mortality from perinatal asphyxia. We think that most babies with severe birth asphyxia born in villages in PNG do not survive to reach hospital and interventions which focus mainly on support for sick neonates (as ours did) are not likely to make a large difference to the outcome from established severe cerebral hypoxia. In the Nigerian study specific effort was put into improved obstetric management of high-risk pregnancies, the prevention of perinatal asphyxia and the early resuscitation

of asphyxiated babies. These interventions are much more likely to be effective, but rely substantially on reforms in obstetric care.

There are remarkably few other trials of neonatal care in developing countries (8-13). Unfortunately, some neonatal trials in developing countries have compared interventions that are only affordable by high-income countries, such as artificial surfactant (11). A non-randomized case-control trial of maternal nursing care versus professional nurses showed a lower mortality with maternal nursing care, but was strongly biased, with lesser severity of illness in the maternal care group (12). There are recent trials of kangaroo mother care (KMC) versus incubator or warm room care in tertiary teaching hospitals (10,13). This alternative style of neonatal care has been shown to be safe and cost-saving for nursing low birthweight babies who are well. In a randomized multicentre trial in teaching hospitals in Ethiopia, Indonesia and Mexico 285 babies weighing 1000-1999 g were treated either with KMC or incubator/warm room care (10). Only 3 babies died in each group (total mortality 2.1%). 434 neonates who fulfilled the weight requirements either died before being enrolled in the trial or were ineligible. This, and the very low death rate in the trial, suggests that the babies were highly selected for having an excellent chance of survival. KMC appears to be an effective alternative form of management in low birthweight babies with a very low risk of mortality, but these trials cannot be applied to the whole population of low birthweight neonates in developing countries. Another smaller study of KMC from Zimbabwe, which showed a lower mortality in those receiving KMC, was not randomized but consecutively allocated (13). Before we instituted the changes to neonatal care in Goroka we considered a change to KMC, but felt this was unlikely to achieve our aim, which was to reduce the overall neonatal mortality. To lower mortality interventions must be targeted towards highest risk rather than lowest risk babies.

Our study was a retrospective analysis of prospectively collected data. In terms of data quality the completeness of the Neonatal Unit admission book is a potential problem. Our independent audit of neonatal deaths showed

the admission book underestimated neonatal deaths by 9%. The independent audit was done by one clinician (TD), who assiduously recorded every death as it happened, and every death was reviewed in the mortality meeting the same week. This two-year independent audit occurred within the intervention phase of the study; we do not have information on admission book data quality from the pre-intervention phase. Omissions in admissions or deaths were unlikely to have biased our comparison over time, however, as recording errors are likely to have persisted during the two periods of study. The same nursing personnel were responsible for keeping the admission book up to date during both periods of the study. However, in the most extreme scenario where the total number of deaths for the entire intervention phase were underestimated by 9%, but no deaths were omitted from the pre-intervention phase data, the number of deaths in the intervention phase would have been 133 ( $122 \times 1.09$ ) compared with 205 pre-intervention (unchanged). The relative risk of death in the intervention phase (after adjustment for the higher number of neonates weighing  $<1.5$  kg in the pre-intervention phase) would then have been 0.64 (95% CI 0.52-0.79,  $p < 0.0001$ ), still a highly significant effect from the changes in practice.

Another aspect to data quality is mortality for specific clinical diagnoses. We thought there might have been diagnostic inconsistency resulting from changes that occurred in medical staff (who recorded the discharge diagnoses on the child's hospital record, but not the actual number of deaths in the admissions book) during the 5 years of the study period. The potential for any such bias is why we combined pneumonia and septicaemia and birth asphyxia and meconium aspiration. The term 'neonatal sepsis' is unfortunately used frequently by health workers for diagnoses including umbilical cord infection, skin pustules, pneumonia or bacteraemia. 'Neonatal sepsis' in turn is sometimes thought to be equivalent to septicaemia. For the purposes of outcome prediction and comparison of performance over time it is useful to be more specific about diagnoses, which we tried to be in the second phase of the study. The previous looser definitions of septicaemia may account for the apparent

marked reduction in admissions from this condition (311 vs 112) and vice versa the higher pneumonia admissions in the intervention period (30 vs 112).

The much higher mortality pre-intervention might conceivably have been due to greater severity of illness in this period. The only objective evidence for this is that there were more low birthweight babies admitted in the pre-intervention phase; however, we have adjusted for this in the data analysis. Conversely there were more neonates admitted overall during the intervention phase compared with the pre-intervention phase. This might suggest that we admitted neonates with lesser severity of illness, who therefore had a better chance of survival during the intervention period. If this were true it would bias the study to a lower mortality in the intervention phase. Apart from the higher number of neonates under 1.5 kg in the pre-intervention period, for which we have adjusted the data, this seems unlikely, as the predominant changes we made were to treatment protocols, not criteria for admission. It seems highly unlikely that severity of illness at presentation was much greater in the pre-intervention phase, as primary rural health services for pregnant women and neonates did not improve substantially during the 5 years of the study, and patterns of illness presentation did not change in other areas. It is conceivable that during the intervention phase neonates were referred or brought to hospital earlier, thereby lessening illness severity at presentation and resulting in better outcomes from hospital treatment. We have no objective data to address this, but we feel this is unlikely to explain the major differences in mortality. Whether such potential confounding and bias affected the comparison of the two time periods and therefore our conclusions could only be resolved by a controlled trial of the two types of neonatal care. Such a trial would be difficult to do, and given our results we feel it would be ethically unsound.

Although we have suggested from these data that the introduction of new technology and treatment protocols will lower neonatal mortality, much of the effect of the changes may have been 'operator dependent'. Human factors are difficult to quantify. It is

impossible to say that the mortality reductions we saw were not due to greater enthusiasm and commitment from the staff in the intervention phase of the study. Some different medical staff were involved for the majority of the two phases, with a 5-month period of overlap in mid-late 1997. We cannot quantify this effect on the mortality risk in the intervention phase, although it may have been substantial. What we can say is that with enthusiasm for lowering neonatal mortality, with training and support for staff who have a reasonable knowledge of the care of critically ill neonates and with some additional low-level technology, in-hospital mortality for sick neonates was reduced by more than 40% and 33 deaths were avoided each year.

It is important to compare the cost-effectiveness of any new interventions with other interventions that will produce a similar outcome. Our technological changes were estimated at US\$445 (K1000) per additional life saved, compared with the older style of more basic neonatal care. This cost estimate does not include nursing or medical staff salaries or drugs, but these were inherent costs prior to the interventions. Nursing manpower in the Neonatal Unit was slightly increased during the intervention phase, but only by recruiting nurses into our paediatric training course. This began in January 1999 and includes considerable time learning high-dependency neonatal care. The estimate of cost per additional life saved only includes lives saved in the 30 months of the study. We could reasonably expect that similar outcomes would occur over the next 5 years, and the technology would last at least that long; therefore the cost per life saved will be much less as time goes on, assuming outcomes are sustained. Overhead heaters and incubators would make up 70% of the cost of setting up a similar neonatal unit. A similar cost-effectiveness study should be done using all other technology (apnoea monitors, oximetry etc) and a similar level of training, but using only a warm room instead of overhead heaters or incubators, to determine whether similar results could be achieved at a much lower cost.

A recent study from India where village birth attendants (VBAs) were trained to give gentamicin and cotrimoxazole to neonates with

simple clinical signs of severe illness lowered mortality substantially and the cost per life saved was estimated at US\$5.30 (9). Barbara Howell, in this issue of the Journal (14), describes her experience with VBAs in remote parts of the Eastern Highlands of PNG, and reports a 74% reduction in combined pregnancy loss and child mortality over 5 years after training 14 VBAs. The costs are not estimated, but these two (non-randomized) community studies suggest that substantial mortality reductions can occur at low cost from village-based interventions. This is not to say that improving hospital-based neonatal care in developing countries is not a worthy endeavour. It is, and it can be done effectively in medium-sized rural hospitals, as we have shown, but good results from even moderate technology medicine may only be achieved at a greater cost per life saved than from some well-managed community-based interventions.

Approximately 10,000 babies are born in Eastern Highlands Province (EHP) each year and the child mortality rate is about 120 per 1000 livebirths. One-quarter to one-third of child deaths occur in the neonatal period. It can therefore be estimated that about 360 neonates die in the EHP annually (120 x 10 x 0.3). The 33 neonatal deaths we estimate were avoided each year because of the interventions represent less than 10% of all neonatal deaths in the province and the total number of neonatal deaths at Goroka Hospital in the pre-intervention period represented less than one-quarter of the province's baseline neonatal mortality. Intervention studies must be compared in terms of both cost per life saved and the proportion of the population reached to establish the most cost-effective uses for scarce health resources in developing countries.

### Conclusions

We have shown that improved supportive care and protocols for the management of high-risk neonates can substantially reduce in-hospital neonatal mortality, but the costs are considerable. Efforts to standardize in-hospital neonatal care should not detract from the fact that throughout PNG most of the neonatal mortality occurs outside hospitals. Lowering in-hospital mortality will result in, at best, a modest reduction in overall neonatal mortality.

Major efforts must also be made to reduce the risk factors for neonatal illness, to provide better antenatal, perinatal and neonatal services within communities and to improve access to high-quality child health facilities.

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## Appendix

### Management protocol for very low birthweight (VLBW) babies (1000-1500 g)

VLBW babies are at risk of apnoea, hypoxaemia, sepsis, feed intolerance and necrotizing enterocolitis. All VLBW babies must be admitted to the Neonatal Unit, regardless of their condition. The consultant must always be notified of the admission.

#### Oxygen

Supplemental oxygen by nasal catheter should be given to all VLBW babies who have an SpO<sub>2</sub> 85% or less, or who have apnoea.

#### Temperature control

VLBW babies should initially be nursed naked under the radiant heater, or in a humidicrib. Aim for a core body temperature of 36-37°C.

#### Fluids

Intravenous fluids at 60 ml/kg/day for the first day of life. Use only paediatric (100ml) intravenous burettes where 1 drop per minute = 1 ml per hour. Do not feed enterally until the condition of the baby becomes clear (never before the second day). Decision when to feed is based on presence of abdominal distension or tenderness, frequency and severity of apnoeas, presence of bowel sounds, passage of meconium and the general condition.

Very small babies under a radiant heater require more fluid than is thought to be the usual maintenance, but great care must be taken to run the intravenous fluids accurately as overhydration may be fatal.

When commencing enteral feeds start with 2-4 ml every 3 hours by nasogastric tube. Use

expressed breastmilk only. If this volume is tolerated without vomiting, abdominal distension or gastric aspirates of more than 1-2 ml, each 3-hourly feed can be increased by 1-2 ml each day. Be prepared to reduce or withhold feeds if signs of poor tolerance occur. Aim to have feeding established in the first 7 days so that the IV drip can be removed, to avoid risk of infection.

#### Glucose

Check blood sugar 6 hourly. Add at least 10 ml of 50% dextrose to every 90 ml of 4.3% dextrose + 1/5 normal saline.

#### Antibiotics

Risk factors for sepsis (and indication for empirical antibiotics): smaller babies (closer to 1 kg), babies born outside hospital or born to unwell mothers, rupture of membranes >24 hours, respiratory distress, apnoea, need for oxygen, umbilical cord inflammation or abdominal distension. Initial empirical antibiotics: benzylpenicillin and gentamicin. Add flucloxacillin if there is skin sepsis, cord infection, eye discharge, soft tissue abscesses or severe systemic sepsis.

#### Aminophylline

This prevents apnoea. Give a loading dose of 10 mg/kg by intravenous injection over 15 minutes at the time of admission. Aminophylline comes in vials of 25 mg/ml, so the usual loading dose will be less than 1 ml. A maintenance dose should be prescribed.

#### Apnoea monitoring

All VLBW babies must be monitored for apnoea. If the apnoea monitor is alarming frequently you should check:

- 1 That the baby is breathing
- 2 That the apnoea capsule is taped on to the abdomen firmly
- 3 That the capsule still has sensitivity to slight pressure
- 4 That the monitor batteries are working.

Do not turn the monitor off if it is frequently alarming without first checking all the above.