MEDICAL PRACTICE

Contemporary Themes

Regional organisation of neonatal intensive care in the North-west

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Summary and conclusions

From January 1976 to July 1978, 234 ill neonates were transported to the regional neonatal intensive care unit (ICU) of St Mary's Hospital, Manchester, from 26 maternity hospitals three to 120 miles (4·8-193·1 km) away. Ninety per cent were transferred from 15 hospitals within a 30-mile (48·3 km) radius of the ICU. Most referring hospitals had more than 2000 births a year and offered good nursing supervision of high-risk neonates in conventional special care baby units (SCBUs). In 200 of the 234 babies respiratory symptoms precipitated referral, hyaline membrane disease being the most common final diagnosis. Altogether 143 babies received definitive mechanical ventilation, and most of them were ventilated in the ambulance en route to the ICU. The neonatal survival rates for all babies and for those who received mechanical ventilation were 61% and 45% respectively. Lethal inoperable malformations and tentorial tears accounted for 23 of the 92 deaths.

A crisis-orientated referral service directed towards the treatment of babies with impending or actual respiratory failure needs close collaboration between the regional ICU and referring SCBUs, with parallel development of their facilities and skills. A complementary but distinct pattern of referral is necessary to cater for those high-risk but not critically ill babies who are born in hospitals that lack staff and facilities to provide the vigilant and anticipatory care that is so necessary.

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Introduction

Several reports have drawn attention to deficiencies in standards of perinatal care in Britain and have recommended improvements.[1-4] Regional organisation of neonatal intensive care has been widely developed in the USA as one aspect of perinatal care programmes[5]; communication with regional administrators in Britain suggests that similar programmes might evolve here. In Britain the feasibility of transporting ill neonates to another hospital to receive intensive care was discussed by Blake *et al.*[6] The number and geographical distribution of maternity hospitals vary from region to region, and standards of neonatal care differ widely among individual maternity hospitals.

These concepts are crucial to the debate on the most appropriate system of regionalisation. We examine the regional neonatal intensive care service for the North-west that operates from St Mary's Hospital, Manchester, and explore its application to other regions.

Staffing and methods

Since 1976 St Mary's Hospital, Manchester, has been the referral centre for intensive care of newborn babies in the region (fig 1). The

FIG 1—Number of neonates referred to regional intensive care unit from different areas in North West from January 1976 to July 1978. Manchester, divided into 3 districts, is shown stippled. St Mary's Hospital is within central district. Referrals from outside region are not shown.

hospital is a teaching maternity hospital catering for 4500-5000 births a year. The neonatal medical unit comprises the regional neonatal intensive care unit (ICU, 10 cots) and the special care baby unit (SCBU, 20 cots). The regional neonatal surgical unit (10 cots) is adjacent to the medical unit. Allocation of nursing staff is based on a ratio of three nurses per cot for the ICU and neonatal surgical unit, and one nurse per cot for the SCBU. Thus the total allocation is 80, but only about 70% are recruited and in post; of those, about 75% are experienced staff (sisters and staff midwives/nurses). Nurse staffing of the ICU flying squad during the night is provided from a rota of experienced nurses who live in accommodation close by the hospital. The Joint Board of Clinical Nursing Studies (JBCNS) course in neonatal intensive care (course 402) is held in the hospital three times a year, and each course accommodates eight nurses. Two clinical teachers (sisters) are employed, one in conjunction with the JBCNS 402 course, the other in relation to the neonatal surgical unit. The medical staffing of the neonatal medical unit is by three senior house officers who have had paediatric experience and one registrar, clinical tutor, and senior registrar. Daily consultant supervision is by a whole-time neonatal paediatrician who has no sessions outside the hospital.

Standard equipment available for each neonate receiving intensive care includes an apnoea monitor, cardio-oscilloscope, skin temperature monitor, ambient oxygen analyser, and an intravenous infusion pump. In addition, the ICU has seven mechanical ventilators, six intra-arterial and three transcutaneous Po_2 monitors, facilities for continuous monitoring and display of arterial blood pressure, and various polygraphic recorders. A whole-time senior physiological measurement technician responsible for care of equipment staffs the unit during the day and together with another technician provides an emergency service at night and weekends. There is a small biochemical laboratory on the unit staffed by a senior medical laboratory scientific officer that contains an automated blood gas analyser and one that is manually operated.

This account is concerned with neonates referred directly to the ICU from other maternity hospitals in the North-western region. The area of the region is 1690 square miles (4377 km^2), its population is about 4 000 000, and in 1977 there were 47 353 live births. The operation of the service was similar to that described by Blake *et al.*[6] When a telephone request was received to transfer an ill neonate from a maternity hospital, a trained doctor and nurse from the ICU travelled in an ambulance to the referring hospital taking with them a portable incubator with a built-in ventilator (Vickers Model 77). The incubator, which was mains (220-240 volt) or battery operated (12 volt) and carried an oxygen cylinder (0·68 m^3), had been extensively modified by the medical physics department of this hospital and incorporated a cardio-oscilloscope, skin temperature monitor, oxygen analyser, and syringe pump for intravascular infusions. Drugs and disposable items of equipment conventionally used for neonatal resuscitation were carried in a separate container.

At the referring hospital a history was taken including a detailed account of antenatal events, a provisional diagnosis was made, and the baby's condition was stabilised; this often entailed the immediate provision of positive-pressure ventilation via a nasotracheal tube. Other measures, including emergency drainage of pneumothoraces, correction of hypoglycaemia, and administration of alkali, were taken when indicated. The parents were encouraged to see their baby before transfer, and a Polaroid photograph was usually taken and given to them. The baby was wrapped in gamgee and silver foil and transported back to the ICU by ambulance; many babies needed to be ventilated en route. Accommodation was available at St Mary's for mothers of transferred babies, but parents were not encouraged to travel in the ambulance with their critically ill baby.

Babies were transferred back to their maternity hospital of birth as soon as they achieved satisfactory blood gases in air and no longer required ventilatory support; at this stage most were being fed by tube and needed close nursing supervision in a SCBU.

Results

From January 1976 to July 1978, 234 neonates were transported from 26 different maternity hospitals situated 3-120 miles (mean ± SD 18·4 ± 18·1 miles) (4·8-193·1 km; mean ± SD 29·6 ± 29·1 km) from the regional ICU: 211 babies (90·2%) were transferred from 15 maternity hospitals in a 30-mile (48·3 km) radius of the ICU. Sixty babies (25·6%) were transported within six hours of birth, 143 (61·1%) within 24 hours, and 189 (80·8%) within 48 hours. The mean ± SD and median birth weights and gestational ages of referred babies were 2119 ± 833 g, 2000 g, 34·0 ± 4·2 weeks, and 33·8 weeks respectively. One hundred and fifty-four babies (65·8%) were low birth weight (LBW, < 2500 g).

Most referring hospitals had more than 2000 births a year and offered good nursing supervision of high-risk neonates and treatment for common neonatal disorders. Only two babies were referred because of low birth weight alone. The indication for transfer in 200 (85·5%) was respiratory signs or symptoms consisting of worsening respiratory distress in 89 (38%), *or* recurrent apnoea complicating respiratory distress in 72 (30·8%), *or* apnoeic attacks alone in 33 (14·1%), *or* solely cyanosis in six (2·6%), *or* failure to breathe from birth in six (2·6%). Hyaline membrane disease was the most common final diagnosis and occurred in 126 (53·8%) babies, of whom 26 (20·6%) were born by elective caesarean section before term for reasons including previous histories of caesarean sections in women thought to be at term, fetal growth retardation, and recurrent antepartum haemorrhage. Their gestational age (mean ± SD) was 33·7 ± 2·6 weeks; in all cases except one antenatal prediction of fetal lung maturity by determination of amniotic lecithin: sphyngomyelin (L: S) ratio had either not been performed or the result was suggestive of pulmonary immaturity with a risk of hyaline membrane disease developing after birth. A lethal untreatable malformation or tentorial tear was the final diagnosis in 23 of the 234 babies.

Mechanical ventilation was necessary in 143 babies (61·1%) (table I). The condition of 37 (15·8%) babies had deteriorated so rapidly

TABLE I—*Neonatal survival rate and incidence of mechanical ventilation in babies of different birth weights referred to the regional intensive care unit*

Birth weight (g)	All babies			Treated with mechanical ventilation	
	No	Survived	(%)	No (%)	Survived (%)
500–1000	19	7	(36·8)	18 (94·7)	7 (38·9)
1001–1500	54	25	(46·3)	38 (70·4)	12 (31·6)
1501–2000	44	26	(59·1)	35 (79·5)	18 (51·4)
2001–2500	37	26	(70·3)	25 (65·6)	16 (64·0)
2501–3000	37	28	(75·7)	16 (43·2)	7 (43·8)
>3001	43	30	(69·8)	11 (25·6)	4 (36·4)
Total	234	142	(60·7)	143 (61·1)	64 (44·8)

Two ventilated babies, birth weights 1000 g and 1230 g, died at 60 days and 30 days respectively.

that the staff of the referring hospital had started ventilation before the ICU crew arrived; 113 babies were ventilated in the ambulance during transportation. The condition of only four of those babies worsened during the journey, which was less than ten miles in each case. Pneumothorax, pneumonia, and bronchopulmonary dysplasia were complications in 31·5%, 19·6%, and 4·3% of all babies who were ventilated. Those with pneumonia had many episodes of endotracheal tube obstruction by mucopurulent secretions. Lobar or segmental collapse, changing its location from day to day, was a common radiological finding.

The neonatal survival rates for all babies and for those who received mechanical ventilation were 60·7% and 44·8% respectively. Survival rates for babies in different birth-weight categories are shown in table I. Inoperable malformations and tentorial tears were responsible for 23 of the 92 deaths; when those lethal conditions were excluded survival rates for all babies and for those who received mechanical ventilation were 67·3% and 53·3% respectively. In babies in whom ventilation had been started before arrival of the ICU crew the survival rate was seven out of 30 (23·3%). Only one baby died in transit. Sixty-three of the 126 babies with hyaline membrane disease survived, and an intraventricular haemorrhage was found at necropsy in 32. This was probably an underestimate because neither a necropsy nor examination of the cerebrospinal fluid was performed in 14 who died with hyaline membrane disease. To examine the efficacy of the ventilatory support facility early neonatal mortality rates of babies born at this hospital during 1970-8 were analysed. The establishment of the regional intensive care service in 1976 and the ability to offer ventilatory support to all inborn babies with respiratory failure reduced mortality by almost 50% (fig 2).

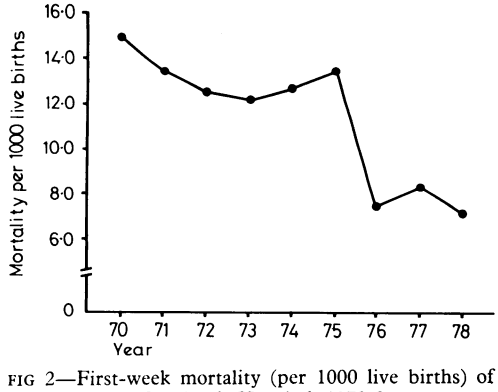

FIG 2—First-week mortality (per 1000 live births) of babies born in St Mary's Hospital, 1970-8.

Babies who survived remained in the ICU for a mean duration (±SD) of 14·8 (±14·1) days. The corresponding duration for those who died was 2·8 (±4·1) days. The need for mechanical ventilation and the occurrence of bronchopneumonia as a complication significantly increased the mean time that affected babies remained in the ICU (table II). The mean (±SD) length of stay of the 23 surviving babies who developed bronchopneumonia while being ventilated was 30·7 (±18·0) days.

TABLE II—*Length of stay in intensive care unit (mean ±SD days) in babies who survived hyaline membrane disease and those who survived complications of mechanical ventilation*

Clinical features	No	Mean ± SD (days)
Hyaline membrane disease		
Ventilated	42	20·1 ± 13·9*
Not ventilated	21	7·1 ± 4·9
All ventilated babies		
Pneumothorax	14	19·7 ± 10·2
No pneumothorax	51	22·4 ± 18·8
Pneumonia	23	30·7 ± 18·0**
No pneumonia	42	16·9 ± 14·9

*P < 0·001 compared with babies not ventilated.
**P < 0·001 compared with babies without penumonia.

Discussion

The size, birth rate, and distribution of maternity hospitals and their facilities differ among regions, and no blueprint for organisation of neonatal intensive care applies to all regions. In our study no fewer than 90% of referrals came from 15 maternity hospitals within a 30-mile radius of the regional ICU. Most of the referring hospitals had over 2000 births a year and offered careful nursing supervision of high-risk neonates and treatment for the common neonatal disorders. This has led to a pattern of referral that is essentially crisis-orientated and directed towards babies with incipient or established respiratory failure.

This concept of a referral service demands that referring SCBUs provide a good level of anticipatory care for high-risk neonates. Each unit should at all times be supervised by at least one nurse trained and experienced in neonatal medicine, and a doctor with neonatal experience should be available at very short notice. Apnoea, heart rate, and skin temperature monitors should certainly be available for all babies who weigh less than 1500 g. Facilities for monitoring ambient oxygen concentrations and arterial blood gases must be available for those babies with respiratory problems so that impending respiratory failure can be recognised. The SCBU staff must be able to carry out promptly short-term positive-pressure ventilation in those babies whose deterioration has been rapid and unpredictable.

Our experience with 23 ill neonates transported from hospitals 31-120 miles away shows that the journey is tolerated well provided intensive care facilities are available en route. Only one baby died in transit, and although several deteriorated this was unrelated to the length of the journey. The disadvantage of long-distance transfers is that they deplete the regional ICU of a trained doctor and nurse for a lengthy period (8-10 hours for referrals 120 miles away). Transfer by helicopter would help to resolve this, but our experience is limited to one such patient not included in the survey.

Inoperable malformations and tentorial tears accounted for 23 of the 92 deaths. In addition at least half of the babies who died with hyaline membrane disease suffered an intraventricular haemorrhage and some had probably sustained their haemorrhage before transfer. The unnecessary referral of certain babies with untreatable lethal conditions is inevitable when the pattern of referral is crisis-orientated. The careful recording of the precise signs and symptoms that precipitate referral to a regional ICU should lead to improved recognition of those clinical features suggestive of a hopeless prognosis.

Our policy is to transfer babies back to their maternity hospital of birth as soon as they no longer need ventilatory support. At that stage most still require careful monitoring of vital signs and feeding by tube. This exemplifies how SCBUs and regional ICUs must develop in parallel, albeit with a different emphasis in care. The occurrence of pneumonia in babies receiving mechanical ventilation prolonged their stay in the ICU. Most of those affected were of very low birth weight and proved to be difficult nursing problems because they required frequent chest physiotherapy and endotracheal tube suction. Their prolonged stay in the unit blocked intensive care cots for new referrals, and this concept must be recognised when planning the cot complements for regional ICUs.

Babies who are not ill but nevertheless are "at risk" perhaps by virtue of prematurity also need close nursing and medical supervision including cardiorespiratory monitoring. So many maternity hospitals in each region have inadequate facilities for caring for high-risk neonates that one or two regional ICUs would be insufficient for the work load if all such neonates were transferred. A referral pattern distinct from that which is crisis-orientated is evolving in some regions where several of the larger district maternity hospitals accept high-risk but not necessarily ill babies born in nearby smaller hospitals. Some hospitals operating this type of service might wish to carry out definitive mechanical ventilation. Our experience suggests that considerable resources and skills are necessary before this can be safely offered to neonates. It is futile to transfer a healthy

premature baby from a small maternity hospital to a nearby larger one, ostensibly to receive a high level of vigilant care, when in practice one baby being ventilated there is diverting attention and limited resources away from the other babies.

The emergence of different patterns of neonatal referral will influence neonatal survival rates and the incidence of long-term handicap reported from individual referral units. The success of intensive care methods in improving neonatal survival is not disputed and is illustrated by the pronounced fall in the early neonatal mortality of babies born in St Mary's since 1976 when mechanical ventilation was introduced on a wide scale. The optimistic long-term prognosis in heterogeneous groups of low-birth-weight babies reported since the introduction of improved neonatal care,[7-9] however, is not applicable to critically ill babies with respiratory failure transferred to a regional ICU.[10 11]

Caution is necessary before advocating the emergency transfer to another maternity hospital of women who develop complications of pregnancy. Our experience of babies referred with severe hyaline membrane disease, however, makes us speculate that when caesarean section is contemplated before term and fetal pulmonary maturation is uncertain or suggestive that hyaline membrane disease will occur women ought to be transferred for delivery to a maternity hospital with the appropriate facilities for definitive mechanical ventilation of neonates.

We conclude that the desirable number and siting of referral ICUs in each region depend on the nature of the referral pattern that is envisaged. Our experience in the North-west suggests that a pattern of referral orientated towards impending or actual respiratory failure is feasible but that it requires close collaboration with referring SCBUs and parallel development of their facilities and skills. A complementary but distinct pattern of referral is necessary to cater for high-risk but well babies born in hospitals that lack the appropriate staff and facilities to provide the vigilant care that is so necessary.

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In My Own Time

Treatment of acute renal failure with artificial kidneys

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Today's patient with acute renal failure has a choice of two effective treatments. Peritoneal dialysis with one- or two-litre bags and a Trocath is relatively safe and can be performed in many district general hospitals. It is even safer when carried out by trained nurses using automated equipment. Even so, it is the more uncomfortable treatment of the two and the one I would avoid for myself if I had a choice.

The alternative is haemodialysis in a renal unit. Soon after admission the patient has a Teflon-Silastic shunt inserted in his forearm, or a Seldinger catheter placed in his subclavian vein with reasonable certainty that it will stay patent as long as it is needed. The consultant prescribes daily or alternate-day dialysis according to the catabolic rate. An efficient well-monitored machine, prepared by a skilled technician, is wheeled to the bedside; it has a double-pump attachment if the subclavian vein catheter is used, rendering a return line unnecessary. A trained nurse connects the patient and monitors the procedure. The sterile, pyrogen-free, disposable dialyser will remove as much fluid by ultrafiltration as she requires, allowing the patient a reasonable fluid intake of up to two litres a day and making total intravenous feeding possible. Between his four-hour dialyses, if his primary disease permits, the patient sits out of bed, eats at a table, and watches television in the day room.

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Bad dreams of the past

It was not always so. In the 1940s and early '50s the conservative treatment of acute renal failure was a grim affair, and included strict fluid restriction that led to intolerable thirst. Patients would climb out of bed, trailing their tubes behind