ORIGINAL ARTICLE

Outcomes for high risk New Zealand newborn infants in 1998–1999: a population based, national study

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Objective: To determine short term morbidity and mortality outcomes, provision of care, and treatments for a national cohort of high risk infants born in 1998–1999 and admitted to New Zealand neonatal intensive care units (NICUs).
Setting: All level III (six) and level II (13) NICUs in New Zealand.
Methods: Prospective audit by the Australian and New Zealand Neonatal Network (ANZNN) of all infants defined as "high risk" (born at < 32 weeks gestation or < 1500 g birth weight, or received assisted ventilation for four hours or more, or had major surgery). Data were collected from birth until discharge home or death.
Results: There were 3368 high risk infants (3.0% of all live births), comprising 1241 (37%) < 32 weeks gestation, 1084 (32%) < 1500 g, 3156 (94%) who received assisted ventilation, and 243 (7%) who received major surgery (categories overlap). Most infants (87%) received some care in tertiary hospitals, and 13% were cared for entirely in non-tertiary hospitals. Survival was 91% for infants < 32 weeks gestation, 97% for infants ⩾ 32 weeks gestation who received assisted ventilation, and 92% for infants ⩾ 32 weeks gestation who had major surgery. The proportion of very preterm infants who survived free of early major morbidity was 11%, 28%, 53%, 81%, and 90% for infants born at < 24, 24–25, 26–27, 28–29, and 30–31 weeks gestation respectively.
Conclusions: These unique population based national data provide contemporary information on the care and early morbidity and mortality outcomes for all high risk infants, whether cared for in hospitals with level III or level II NICUs.

Population based studies on the provision of care and outcomes of high risk infants are essential for the evaluation of perinatal care services and neonatal intensive care programmes. They minimise selection bias and thus provide a more accurate view of the population than institution based studies.[1] Literature reporting outcomes of infants admitted to neonatal intensive care units (NICUs) tend to focus on those most preterm or with the lowest birth weights, of which few are population based.[2–8] Furthermore, many studies report only those infants admitted to NICUs with full facilities to care for critically ill infants (level III NICUs)[9] or only inborn infants,[10] reflecting a different case mix from the infants receiving intensive care in hospitals with special care facilities to manage mildly ill infants (level II NICUs).

In New Zealand, the short and long term outcomes of the national population of very low birthweight infants (< 1500 g) and those < 28 weeks gestation, who were live born in 1986 and admitted to a neonatal unit, have been reported as part of a prospective study of retinopathy of prematurity (ROP).[11–16] However, there are no published New Zealand data and few international population based studies[9 17] reporting outcomes for a broader range of high risk infants, such as those who receive assisted ventilation or have major surgery. There are also no contemporary New Zealand data on outcomes for very preterm infants (< 32 weeks gestation) reported by gestational age, which is most useful for facilitating decision making in obstetrics. Recent data are the most informative and reflect current practices in neonatal care, as the last decade has seen the introduction of new treatments and evolving modes of ventilatory support.

Neonatal networks play an important role in evaluating neonatal intensive care practices and outcomes and assisting with quality improvement.[18 19] The Australian and New Zealand Neonatal Network (ANZNN) conducts a prospective audit of high risk infants admitted to neonatal units. Since 1995, all 29 hospitals with level III NICUs in Australia and New Zealand have formed part of this network. New Zealand has a population of 3.8 million people, with an infant death rate of 5.6 per 1000,[20] and there are six regional hospitals with level III NICUs.

The aim of this study was to determine the current population based morbidity and mortality outcomes until discharge home, and the provision of care and treatments for all high risk infants born in 1998–1999 and admitted to New Zealand NICUs. To meet the study objectives, the ANZNN expanded to include all 13 hospitals with level II NICUs in New Zealand, ensuring unique, comprehensive data for the entire New Zealand population of high risk infants born in 1998–1999 and admitted to tertiary or non-tertiary hospitals.

Data are reported for the following high risk groups: infants of less than 32 weeks gestation; infants born at 32 weeks or more who received assisted ventilation; infants born at 32 weeks or more who received major surgery. Data on infants of birth weight less than 1500 g are presented in the following paper.[21]

STUDY POPULATION AND METHODS

The study population comprised all infants who were born alive between 1 January 1998 and 31 December 1999, admitted to a

Abbreviations: NICU, neonatal intensive care unit; ANZNN, Australian and New Zealand Neonatal Network; IPPV, intermittent positive pressure ventilation; CPAP, continuous positive airways pressure; GA, gestation; CLD, chronic lung disease; NEC, necrotising enterocolitis; ROP, retinopathy of prematurity; IVH, intraventricular haemorrhage; HMD, hyaline membrane disease.

hospital with a level II or level III NICU in New Zealand, and met the ANZNN's "high risk" criteria: born at less than 32 completed weeks gestation, or born weighing less than 1500 g (very low birthweight), or received assisted ventilation (intermittent positive pressure ventilation (IPPV) and/or continuous positive airways pressure (CPAP)) for four or more consecutive hours, or had major surgery (defined as the opening of a body cavity).

Infants were only included if admitted to a NICU during their first hospital stay and within 28 days of birth. Infants who died in the labour ward were excluded.

All hospitals with level III NICUs (herein referred to as "level III hospitals" or "tertiary hospitals"; n = 6) and all hospitals with level II NICUs (herein referred to as "level II hospitals"; n = 13) in New Zealand participated in the study, as part of the ANZNN's audit. All hospitals that cared for sick newborn infants and all infants born in New Zealand who met the ANZNN high risk criteria were included in the study.

New Zealand has a regionalised system of perinatal and neonatal care, with tertiary hospitals located in the major cities and coordinating the care of most high risk pregnancies and critically ill infants within their geographic region. Neonatal intensive care and special care is fully state funded, with the funding pattern reflecting the regionalised nature of the service. Level III NICUs provide full intensive care facilities including long term assisted ventilation and neonatal surgery. Level II hospitals, which are all related to the regional level III hospital, care for infants over 32 weeks gestation or 1500 g birth weight, and requiring short term ventilatory assistance only, although four level II+ hospitals also provide care for some infants over 28 weeks or 1000 g birth weight and do provide continuing nasal CPAP but not endotracheal ventilation. Level I hospitals are local hospitals with no facilities for sick newborns.

Data were collected prospectively by staff at the participating neonatal units, either on ANZNN forms or by incorporating the necessary variables into their local database. There were 68 data variables, which related to maternal and pregnancy risk factors, birth, treatment, and mortality and morbidity outcomes, until death or discharge home. Transfer details were recorded and date of discharge home as well as other relevant outcome information was sought from the transfer hospitals. The 30 (0.89%) infants whose discharge date was not available from the transfer hospital were assumed to have survived to go home. Missing or anomalous data were identified and queried at entry into the ANZNN database. Quality checks were performed to identify outliers, duplicates, abnormal dates, or other anomalous data, and consistency of information. Confidentiality guidelines, as outlined in the reports, were strictly adhered to and no patient identifying information was collected.

Gestational age (GA) was reported in completed weeks of gestation, from the first day of the last menstrual period, or by prenatal and/or postnatal clinical assessment when accurate information on the last menstrual period was not available. Data are reported according to the four high risk criteria, in gestational age categories, with very low birthweight infants reported in detail in the following paper.[21] Very preterm infants were defined as 20–31 weeks GA, extremely preterm as < 28 weeks GA, moderately preterm as 28–31 weeks GA, mildly preterm as 32–36 weeks GA, and term as 37–44 weeks GA.[22]

Definitions were developed by the members of the ANZNN and are reported in the ANZNN annual reports.[23 24] Major congenital malformations were coded according to the International Classification of Diseases, 9th revision.[25] Infection was defined as a proven episode of bacterial, fungal, or viral systemic infection.[26] Chronic lung disease (CLD) was defined as the need for respiratory support (oxygen, CPAP, or IPPV) at 36 weeks of corrected postmenstrual age for infants born at less than 32 weeks GA. A major neonatal morbidity was defined as having at least one of the following: CLD, definite necrotising enterocolitis (NEC),[27] retinopathy of prematurity (ROP) stage 3 or 4,[28] intraventricular haemorrhage (IVH) grade 3 or 4,[29] periventricular leucomalacia, porencephalic cyst, or hydrocephalus. One "day" of assisted ventilation was defined as four or more consecutive hours of assisted ventilation in any 24 hour period.

To improve the generalisability of the outcomes for very preterm infants, the ANZNN data were compared with New Zealand national statistics[30] for the calendar year 1999 (data were not available for 1998) to determine the number of live-born and stillborn infants not included in the cohort. For infants < 32 weeks GA, values where the birthweight category was more than 4 standard deviations outside the mean for the infant's gestation and sex[31] were excluded (n = 24), these being assumed to be data errors. Registered live births were defined as those born showing some evidence of life, irrespective of gestational age. Registered stillbirths were defined as babies born without signs of life who either weighed 400 g or more or were born after 20 weeks GA.

Infants admitted directly to either Starship Children's Hospital or Greenlane Hospital in Auckland for paediatric or cardiac intensive care were not eligible for this study if they were not admitted to any level II or level III NICUs. Infants cared for exclusively in non-tertiary hospitals for the first 28 days were registered to that level II hospital. Infants admitted to or transferred to a level III hospital within 28 days of birth were registered to the first level III hospital in which they remained for four or more hours.

Statistical analyses were performed using SAS version 8. The Mantel-Haenszel test for trend (χ^2_1) was used to analyse trends in proportions for dichotomous variables. Statistical significance was defined at the $p < 0.05$ level.

RESULTS

Number of high risk infants

During 1998–1999, there were 3368 infants in New Zealand who met the ANZNN's definition of high risk. This cohort represented 3.00% of the 112 402 New Zealand live births for the same years.[20] Grouped according to the four high risk registration criteria, there were 1241 (37%) infants born at < 32 weeks GA, 1084 (32%) at < 1500 g, 3156 (94%) who received assisted ventilation for four hours or more, and 243 (7%) infants who received major surgery (categories overlap). The number of infants registered to each NICU during the two year period ranged from 157 to 954 for level III hospitals and 0 to 86 for level II hospitals.

Characteristics of the cohort

Table 1 shows the characteristics of the cohort of all 3368 high risk infants.

Antenatal characteristics

The majority (64%) of the mothers were caucasian, with a further 21% identified as Maori and 9% as Pacific Islander. For infants born at < 37 weeks GA, the predominant obstetric problem that led to their preterm birth was preterm labor (33%). Other problems leading to preterm birth were hypertension in pregnancy (17%), preterm, prelabour rupture of membranes (14%), and antepartum haemorrhage (11%). Many (45%) term births had no identifiable antenatal problems, and 22% had fetal distress as their main antenatal problem.

The mothers of 63% of infants were booked at the hospital where the infant was registered for the audit, comprising 51% booked at a level III hospital and 12% booked at a level II hospital. Of infants who were registered to a level II hospital for their care, 90% of mothers were booked. Extremely preterm infants had the highest proportion of in utero transfers (41%) to their registration hospital and term infants had the highest proportion transferred after birth (33%). The majority (59%)

Table 1 Characteristics of the high risk cohort divided into gestational age groups (weeks)

Characteristics	21–27 (n=397)	28–31 (n=844)	32–36 (n=1244)	37–44 (n=883)	All (n=3368)
Maternal ethnicity					
Maori	91 (23)	183 (22)	226 (19)	184 (21)	684 (21)
Pacific Islander	39 (10)	62 (7)	86 (7)	111 (13)	298 (9)
Caucasian	241 (61)	533 (64)	844 (69)	511 (60)	2129 (64)
Asian	24 (6)	47 (6)	56 (5)	36 (4)	163 (5)
Source of referral to hospital					
Booked at hospital	176 (48)	453 (62)	750 (71)	491 (62)	1870 (63)
In utero transport	149 (41)	229 (31)	189 (18)	31 (4)	598 (20)
Ex utero transport	35 (10)	45 (6)	109 (10)	257 (33)	446 (15)
Other	6 (2)	8 (1)	9 (1)	10 (1)	33 (1)
Place of birth					
Level III hospital	358 (90)	714 (85)	933 (75)	478 (55)	2483 (74)
Level II hospital	30 (8)	105 (12)	255 (21)	219 (25)	609 (18)
Infants from multiple birth	93 (23)	257 (30)	276 (22)	18 (2)	644 (19)
Male sex	221 (56)	447 (53)	732 (59)	552 (63)	1952 (58)
Intubated at resuscitation	295 (74)	216 (26)	143 (12)	172 (20)	826 (25)
Apgar score <4 at 5 min	25 (6)	10 (1)	17 (1)	47 (5)	99 (3)
Major congenital malformation	14 (4)	48 (6)	83 (7)	163 (19)	308 (9)

Values are numbers with percentages in parentheses.

of infants transferred ex utero were accompanied by a retrieval team with specialist neonatal training.

Place of birth and place of care

Overall, 2483 (74%) infants in the cohort were born in a level III hospital, decreasing from 90% at 21–27 weeks gestation to 55% at term. Another 609 (18%) infants were born in level II hospitals, and 188 (6%) were born in a level I hospital. Of infants born in a level II hospital, 188 (31%) were transferred to a level III hospital during their hospital stay, the highest proportion at < 28 weeks GA (77%), followed by term infants (37%), infants 28–31 weeks GA (27%), and infants 32–36 weeks GA (22%). Most (80%) of these transfers occurred within one day of birth.

There were 2917 (87%) high risk infants who were admitted to a level III NICU within 28 days of birth, including 98% of infants < 28 weeks GA and 90% of infants 28–31 weeks GA, and their care was registered to the level III hospital. Level II hospitals cared entirely for the remaining 451 (13%) high risk infants, including 7% at < 32 weeks. Of infants registered to level III hospitals, 688 (24%) were transferred to a non-tertiary hospital before going home, the majority (n = 490, 71%) going to a level II hospital. Very preterm infants accounted for 56% of those back transferred to level II hospitals, at a median of 32.4 weeks equivalent gestation, with 11% continuing to receive assisted ventilation after transfer. Overall, 996 (30%) of all infants in the cohort were admitted to a level II hospital for care at some time before discharge home. Some infants were transported between level III hospitals (n = 100, 3%), or to Greenlane or Starship Hospitals for specialist care or surgery (n = 88, 3%). Altogether, 44% of infants were involved in at least one episode of antenatal or neonatal transport.

Infant characteristics and condition at birth

Most infants were male (58%), particularly term infants (63%), and 19% of infants were from a multiple birth. At birth, 25% of infants received intubation at resuscitation, and 3% had an Apgar score of less than 4 at five minutes; however, these proportions were highest for extremely preterm infants (74% and 6% respectively). Some 19% of term infants in the cohort had a major congenital malformation that was diagnosed before discharge.

Very preterm infants (< 32 weeks gestation)

Table 2 shows the treatments used for very preterm infants and their morbidity and mortality outcomes.

Treatments

Antenatal corticosteroids were given to the mothers of 83% of very preterm infants and 79% of infants < 34 weeks GA, with 74% and 73% respectively receiving the recommended completed course of two doses within seven days of birth. Exogenous surfactant was given to 90% of very preterm infants with hyaline membrane disease (HMD) who received IPPV.

Morbidity and mortality

Screening for ROP was reported for 69% of very preterm infants, but increased to over 90% for infants < 28 weeks GA. However, the New Zealand recommendations during this period were that screening should be conducted in all infants < 31 weeks GA or < 1250 g,[32] and according to this criterion, 76% of eligible infants were reported to be "examined". For the group for which screening was recommended, 18% of examined infants developed stage 1 or 2 ROP, and 3% developed stage 3 or 4 ROP, rates similar to those reported for all infants < 32 weeks GA (table 2). Treatment for ROP was given to 11 infants (1.4% of infants < 32 weeks who survived and were examined for ROP), all of whom were < 28 weeks GA.

Overall, 1116 (90%) very preterm infants had an ultrasound or postmortem examination during the first 10 days of life to detect IVH. A quarter (24%) of the infants who did not have an initial head ultrasound had died during the first 10 days. For the 638 (57%) infants who had a late head ultrasound recorded more than 20 days after birth and were alive at discharge, a low incidence of cerebral abnormalities was detected (hydrocephalus 1.3%, periventricular leucomalacia 1.6%, porencephalic cysts 2.7%). A total of 72 (6%) very preterm infants had major surgery, including 32 (22%) infants at 24–25 weeks GA.

Decreasing gestational age was significantly associated with increasing rates of morbidities, including infection, NEC, CLD, any stage of ROP, any grade of IVH, and decreasing survival ($p < 0.001$). Infants < 24 weeks GA had the lowest survival rate (42%) and the lowest proportion of infants surviving free of early major morbidity (11%). There were no survivors born at < 23 weeks GA (n = 3), nor born at both < 24 weeks GA and < 500 g (n = 4). Overall, 1129 (91.0%) very preterm infants survived to discharge home. Of the 112 infants who died, 76 (68%) died within seven days, and 20 (18%) deaths were directly attributable to a major congenital malformation. Excluding those with lethal congenital malformations, 92.5%

Table 2 Treatments and outcomes for very preterm infants (< 32 weeks gestation) divided into gestational age groups (weeks)

Treatments and outcomes	<24 (n=19)	24–25 (n=148)	26–27 (n=230)	28–29 (n=345)	30–31 (n=499)	All <32 (n=1241)
Antenatal corticosteroids*	9 (69)	97 (82)	145 (82)	221 (82)	319 (84)	791 (83)
Surfactant for HMD**	10 (83)	102 (89)	139 (94)	145 (93)	94 (81)	490 (90)
Proven systemic infection	7 (37)	79 (53)	96 (43)	84 (24)	59 (12)	325 (26)
Proven necrotising enterocolitis	0 (0)	15 (10)	12 (5)	9 (3)	5 (1)	41 (3)
Respiratory morbidity						
Received assisted ventilation	19 (100)	147 (99)	230 (100)	331 (96)	417 (84)	1144 (94)
Air leak requiring drainage	3 (16)	16 (11)	14 (6)	17 (5)	15 (3)	65 (5)
Oxygen at 36 weeks PMA†	6 (75)	44 (42)	56 (28)	30 (9)	23 (5)	159 (14)
Resp support at 36 weeks PMA†	6 (75)	49 (47)	61 (30)	33 (10)	23 (5)	172 (15)
Home oxygen therapy‡	4 (50)	25 (24)	31 (15)	8 (2)	5 (1)	73 (6)
Days of assisted ventilation§	77 (68,83)	60 (49,72)	40 (28,54)	13 (6,28)	4 (2,7)	11 (4,37)
ROP						
Examined for ROP‡	8 (100)	99 (93)	181 (91)	252 (77)	235 (49)	775 (69)
Stage 1 or2l	3 (38)	38 (38)	43 (24)	37 (15)	6 (3)	127 (16)
Stage 3 or 4	2 (25)	13 (13)	5 (3)	1 (0)	1 (0)	22 (3)
Intraventricular haemorrhage						
Early ultrasound recorded	15 (79)	138 (94)	221 (96)	334 (97)	408 (82)	1116 (90)
Grade 1 or 2	2 (13)	20 (14)	40 (18)	39 (12)	27 (7)	128 (11)
Grade 3 or 4	5 (33)	21 (15)	19 (9)	13 (4)	1 (0)	59 (5)
Late ultrasound recorded‡¶	4 (50)	89 (84)	145 (72)	210 (64)	190 (39)	638 (57)
Hydrocephalus	0 (0)	5 (6)	0 (0)	3 (1)	0 (0)	8 (1)
Periventricular leucomalacia	0 (0)	3 (3)	1 (1)	4 (2)	2 (1)	10 (2)
Porencephalic cysts	0 (0)	2 (2)	8 (6)	4 (2)	3 (2)	17 (3)
Survived to discharge home	8 (42)	106 (72)	201 (87)	328 (95)	486 (97)	1129 (91)
Survived free of major morbidity	2 (11)	41 (28)	123 (53)	281 (81)	451 (90)	898 (72)
Length of stay (days)‡	125 (114,135)	106 (95,122)	82 (70,98)	61 (53,72)	42 (34,51)	59 (43,79)
PMA at discharge home (weeks)‡	40.8 (39.2,42.2)	39.7 (38.4,41.5)	38.3 (36.9,40.1)	37.4 (36.1,38.4)	36.4 (35.6,37.7)	37.3 (36.0,39.0)

Data are presented as number (%) or as median (25th,75th centiles). Outcomes of ROP examinations and head ultrasounds are presented as a percentage of those examined.
*Excludes data for two neonatal intensive care units for which data were unavailable.
**For infants who received intermittent positive pressure ventilation for ⩾ 4 hours and had a respiratory diagnosis of HMD.
†Of infants surviving to 36 weeks PMA.
‡Of infants who survived to go home.
§For infants who received assisted ventilation and survived to go home.
¶Late head ultrasound defined as a head ultrasound recorded >20 days after birth.
HMD, Hyaline membrane disease; PMA, postmenstrual age; ROP, retinopathy of prematurity.

of very preterm infants survived. Overall, 20% of very preterm infants who were discharged home had a major neonatal morbidity, significantly decreasing from 75% at < 24 weeks GA to 61%, 39%, 14% and 7% at 24–25, 26–27, 28–29, and 30–31 weeks GA respectively ($\chi^2_1 = 210.1$, $p < 0.001$). The median postmenstrual age when discharged home decreased with increasing gestation at birth, and overall 83% of very preterm infants went home before their estimated date of birth.

Live births and stillbirths not in ANZNN data

In New Zealand in 1999, there were 222 registered births of < 24 weeks GA, of which 158 (71%) were stillborn, and 64 (29%) were live born. Of those born alive, 11 (17%) were admitted to an NICU and thus included in this study. Hence, in 1999, 3% of all infants (including live born and stillborn) born at 20–23 weeks GA survived, and 9% of all liveborn infants born at 20–23 weeks GA survived. In this study, 42% of the infants born in 1998–1999 at < 24 weeks GA and admitted to a NICU survived. For infants born at 24–31 weeks GA, ANZNN reported an extra 18 infants compared with the national statistics. A further 82 infants were stillborn at 24–31 weeks GA (11% of all infants born at 24–31 weeks GA). Of infants born at 32 weeks GA, 57% of liveborn infants were in the ANZNN cohort, with the percentage of infants in the cohort decreasing with increasing gestational age, to less than 1% for infants at 39–43 weeks.

Treatments and outcomes for infants ⩾ 32 weeks gestation who received assisted ventilation for four hours or more (excluding infants who had major surgery)

The most common indications for respiratory support for these infants were non-specific respiratory distress (includes transient tachypnoea of the newborn, 38%) and HMD (27%) (table 3). The respiratory diagnoses were more heterogeneous with increasing gestational age. The predominant mode of assisted ventilation was CPAP only (n = 1415, 76%). A combination of IPPV and CPAP was given to 289 (15%) infants, and 168 (9%) infants received IPPV only. Respiratory treatments administered to infants receiving IPPV included nitric oxide (n = 78, 17%), high frequency ventilation (n = 22, 5%), and extracorporeal membrane oxygenation (n = 5, 1%). The main respiratory diagnoses for infants receiving nitric oxide were primary pulmonary hypertension (n = 29) and meconium aspiration (n = 19), and for infants receiving high frequency ventilation the most common diagnosis was HMD (n = 7, 32%).

Supplemental oxygen was administered to 83% of infants. The median duration of assisted ventilation and oxygen treatment was relatively consistent at one to three days in all gestational age groups. A total of 1812 (96.8%) infants in this high risk group survived to discharge home. Survival increased to 98.4% if infants with lethal congenital malformations (n = 30, 50% of deaths) were excluded. The length of stay of survivors decreased from a median of 26 days at 32–33 weeks GA to seven days at term.

Treatments and outcomes for infants ⩾ 32 weeks gestation who had major surgery

There were 171 infants ⩾ 32 weeks gestation who received major surgery: 61 infants at 32–36 weeks GA and 110 term infants (table 4). There was a high proportion of infants with at least one major congenital malformation (77% at 32–36 weeks GA and 91% at term) in this high risk group, and this was their predominant reason for respiratory support. The survival rate to discharge home was 92.4% overall, including

Table 3 Treatments and outcomes for infants ≥32 weeks gestation who received assisted ventilation for ≥4 hours

Treatments and outcomes	32–33 weeks (n=474)	34–36 weeks (n=626)	37–38 weeks (n=285)	39–40 weeks (n=313)	>40 weeks (n=174)	All ≥32 (n=1872)
Reason for respiratory support						
Hyaline membrane disease	182 (41)	211 (37)	51 (20)	14 (5)	10 (6)	468 (27)
Non-specific respiratory distress	189 (43)	251 (44)	99 (38)	89 (30)	37 (22)	665 (38)
Pneumonia	20 (5)	40 (7)	35 (13)	42 (14)	15 (9)	152 (9)
Newborn encephalopathy	3 (1)	3 (1)	13 (5)	23 (8)	12 (7)	54 (3)
Pulmonary hypertension	2 (0)	6 (1)	8 (3)	24 (8)	10 (6)	50 (3)
Meconium aspiration	0 (0)	1 (0)	12 (5)	57 (19)	54 (32)	124 (7)
Congenital malformation	3 (1)	11 (2)	9 (3)	16 (5)	9 (5)	48 (3)
Mode of assisted ventilation						
IPPV + CPAP	74 (16)	85 (14)	50 (18)	45 (14)	35 (20)	289 (15)
CPAP only	375 (79)	507 (81)	205 (72)	212 (68)	116 (67)	1415 (76)
IPPV only	25 (5)	34 (5)	30 (11)	56 (18)	23 (13)	168 (9)
Days of assisted ventilation*	2 (1,4)	2 (1,4)	2 (1,4)	1 (1,2)	2 (1,3)	2 (1,4)
Days of supplemental oxygen*	2 (1,4)	3 (1,5)	3 (1,5)	2 (1,4)	2 (1,4)	2 (1,5)
Respiratory treatments†						
High frequency ventilation	5 (5)	4 (3)	1 (1)	7 (7)	5 (9)	22 (5)
Nitric oxide	5 (5)	8 (7)	16 (20)	21 (21)	28 (48)	78 (17)
Air leak requiring drainage	14 (3)	31 (5)	22 (9)	14 (5)	9 (5)	90 (5)
Survived to discharge home	470 (99)	620 (99)	273 (96)	284 (91)	165 (95)	1812 (97)
Length of stay (days)‡	26 (22,34)	15 (11,20)	9 (6,12)	7 (5,10)	7 (5,11.5)	14 (8,24)
PMA at discharge home (weeks)‡	36.3 (35.6,37.3)	37.1 (36.6,37.7)	38.9 (38.3,39.4)	40.9 (40.4,41.1)	42.4 (41.9,43.0)	37.9 (36.6,40.1)

Data are presented as n (%) or as median (25th,75th centiles) and exclude infants ≥32 weeks who had major surgery.
*For infants who received this treatment and survived to go home.
†For infants who received IPPV.
‡For infants who survived to go home.
IPPV, Intermittent positive pressure ventilation; CPAP, continuous positive airways pressure; PMA, postmenstrual age.

89% for mildly preterm infants and 95% for term infants. Nine (69%) deaths were attributable to a major congenital malformation. Excluding those infants, 97.5% survived overall. The median length of stay was 41 days for infants 32–36 weeks GA and 19 days for term infants.

DISCUSSION

This paper describes the current care, treatments, and early morbidity and mortality outcomes for a national cohort of high risk infants born in 1998–1999 and admitted to neonatal units in New Zealand. These data are unique, because they include infants admitted to all neonatal units in New Zealand, including tertiary and non-tertiary hospitals; they are population based and include a national cohort of high risk infants born during a two year period; and represent the spectrum of infants cared for in NICUs, as they include all infants who were very preterm, with very low birth weight, received assisted ventilation, or had major surgery. These data also provide insight into the regionalisation and management of neonatal services in New Zealand, as all level III and level II NICUs participated in this study.

Table 4 Treatments and outcomes for infants ≥32 weeks gestation who had major surgery

Treatments and outcomes	32–36 weeks (n=61)	37–44 weeks (n=110)
Major congenital malformation	47 (77)	100 (91)
Antenatal diagnosis of fetal malformation	19 (46)	29 (43)
Assisted ventilation for ≥4 hours	59 (97)	81 (74)
Mode of assisted ventilation*		
IPPV + CPAP	23 (39)	13 (16)
CPAP only	3 (5)	6 (7)
IPPV only	33 (56)	62 (77)
Reason for respiratory support†		
Perisurgical support	11 (18)	21 (25)
Congenital malformation	22 (37)	40 (48)
Days of assisted ventilation‡	4.5 (3,9)	3 (1,4)
Days of supplemental oxygen‡	5 (2,19)	4 (2,9)
Respiratory treatments§		
High frequency ventilation	8 (14)	3 (4)
Nitric oxide	3 (5)	6 (8)
Survived to discharge home	54 (89)	104 (95)
Length of stay (days)¶	41 (24,57)	19 (13,31.5)
PMA at discharge home (weeks)¶	39.9 (38.0,42.9)	42.1 (40.7,43.6)

Data presented as n (%) or as median (25th,75th centiles).
*For infants who received assisted ventilation.
†For infants who received respiratory support (IPPV, CPAP or supplemental oxygen).
‡For infants who received this treatment and survived to go home.
§For infants who received IPPV.
¶For infants who survived to go home.
IPPV, Intermittent positive pressure ventilation; CPAP, continuous positive airways pressure; PMA, postmenstrual age.

There is a consensus that the birth and subsequent care of the extremely preterm infant should occur in regionalised, perinatal centres, with full facilities for neonatal intensive care,[2 3 15 22 33] and that antenatal transfer of the mother is the ideal mode of transport to the tertiary centre of care.[34–36] New Zealand has a well established system of regionalisation for neonatal intensive care. In this study, 93% of extremely preterm infants were born in a level III hospital, achieved in part by their high rate (41%) of in utero transfers. Only 3% of infants in the cohort were transported between level III hospitals, suggesting a suitable allocation of intensive care beds and resources during the study period.

However, there are few studies on the most appropriate place of birth for high risk infants at more mature gestations. Berg *et al*[37] reported that for women who gave birth to infants weighing 2500 g or more and who developed a complication of labor, neonatal mortality at level I hospitals was increased compared with higher level hospitals, regardless of their prepartum risk status. They suggest referral of high risk women to level II or III hospitals for term delivery. However, in the New Zealand cohort, 45% of the mothers of term infants had no identifiable antenatal problems, and this may explain the high rate (33%) of transport after birth for term infants.

Level III hospitals provided most of the care for this high risk cohort, but the level II hospitals played an integral role in that care. They stabilised infants before transport when necessary, cared entirely for 13% of all high risk infants, and provided continuing care for another 17% of infants once discharged from level III hospitals, particularly those born very preterm. This is an efficient means of conserving resources and reducing pressure on the level III hospitals. Furthermore,

level II hospitals are often geographically isolated from the larger cities where the level III hospitals are located. The social, psychological, and economic impact on the family of antenatal and neonatal transfers to tertiary hospitals is an important yet understudied aspect of neonatal care. The inclusion of level II hospitals in existing neonatal networks is feasible and also ensures the completeness of data with regard to further treatment, eye examinations, and head ultrasounds on back transfer.

However, it is important to ensure that there is appropriate follow up of very preterm infants after back transfer, and our data suggest that performing eye examinations is one area where follow up could be improved. Not only is it imperative that infants have a retinal examination by someone experienced in indirect ophthalmoscopy, according to the national guidelines,[32] but this should also be at the appropriate time to allow treatment should this be necessary.

One of the objectives of the ANZNN is to assess the uptake into clinical practice of evidence based recommendations such as those by the National Health and Medical Research Council of Australia[22] and the Cochrane database of systematic reviews. One such recommendation is that antenatal corticosteroids should be considered for all imminent births at < 34 weeks GA,[22] in order to reduce mortality and the incidence of respiratory distress syndrome and IVH.[38] New Zealand scientists were the first to trial this treatment in 1970,[39] and New Zealand continues to have one of the highest rates of antenatal corticosteroid administration (83% and 79% for infants < 32 weeks GA and < 34 weeks GA respectively, compared with 58% for infants < 34 weeks GA in the Canadian NICU Network in 1996–1997,[9] 71% for infants 501–1500 g in the NICHD Neonatal Network 1995–1996,[10] and 51% for infants < 32 weeks GA in northern and eastern France[40]), as well as a high proportion (73%) receiving the recommended course. Another recommended treatment is the administration of exogenous surfactant for preterm infants with HMD who receive IPPV.[41] Some 90% of very preterm infants in this category received this treatment, which compares favourably with other studies.[40 42]

Overall, 91% of infants < 32 weeks GA in this high risk cohort survived to go home, increasing from 42% at < 24 weeks GA to 97% at 30–31 weeks. These survival rates are encouraging compared with other recent studies. A population based study in Trent, United Kingdom, of infants born at < 33 weeks GA in 1997 and admitted to a neonatal unit, reported 88% survival to 36 weeks corrected premenstrual age.[43] Also for the year 1997, eight level III NICUs in France reported 86% survival for infants born at < 32 weeks GA, despite a smaller proportion of infants < 25 weeks GA (7% in the French study *v* 13% in New Zealand).[40]

Reporting outcomes by gestational age rather than birth weight is more useful for decision making before birth, and is considered a better predictor of outcome for the extremely preterm infant.[44 45] However, the ANZNN's audit criteria did not include liveborn infants who died in the labor ward, nor stillborn infants, which affects the generalisability and interpretation of these survival and morbidity rates, particularly for the extremely preterm infant.[1] This limitation was overcome by comparing these data with national birth registrations for 1999,[30] which showed that the "true" survival rate for infants born at 20–23 weeks was 9% for liveborn infants, and 3% including stillbirths. These survival rates suggest that the prognosis for infants at the limits of viability has not changed in the last decade.[46 47] The NICU admission rates in this study for liveborn infants at 20–23 weeks gestation (17%) are lower than those reported in the United Kingdom and Ireland (29%),[48] but the overall survival rate for these liveborn infants, irrespective of whether admitted to an NICU, was higher in this study (9% *v* 6% in the United Kingdom and Ireland).

For infants born at 24–31 weeks GA in 1999, an extra 18 infants were reported by the ANZNN compared with the national registration of births for that year. This difference is probably due to delays in the national registration of births during that year.[20] However, although we cannot be certain of the actual number of labor ward deaths at 24–31 weeks GA, these data suggest that all of these liveborn infants were included in this study. National demographic data[20] also show that the proportion of the infants' mothers who identified themselves as Maori (21%) and Pacific Islander (9%) in this study was comparable to the national maternal population, suggesting that these infants were not over-represented in this high risk cohort.

Numerous studies have shown that very preterm and very low birthweight infants with early neonatal morbidities have an increased risk of adverse long term neurological, functional, educational, and behavioural outcomes.[5 13–16 49–51] Overall, 72% of all very preterm infants in this cohort survived to discharge and had no early major morbidity identified. These rates are similar to those reported by other NICU networks. The NICHD Neonatal Research Network reported 71% survival without major morbidity (defined as grade 3 or 4 IVH, CLD, or NEC) for infants 501–1500 g.[10] The Canadian NICU Network reported 69% survival without major morbidity for infants < 1500 g, classifying major morbidity as CLD, NEC, grade 3 or 4 IVH, or stage 3 or 4 ROP.[9]

There are few studies relating to the short and long term morbidities for high risk term infants, but there is some evidence that infants of birth weight≥ 3500 g who are depressed at birth, or have a diagnosis of asphyxia, or have major congenital anomalies have a poor prognosis.[17 52] A recent population based study showed that mechanically ventilated term infants had more major disability (17.2%) than control infants (1.6%) at 3 years of age.[53] A prospective study of 30 full term infants who had major neonatal surgery reported developmental delay at 1 year of age[54] and lower cognitive functioning at 3 years.[55] Length of hospital stay[54] and number of operations[55] were strongly associated with poorer outcome. In New Zealand, infants of ⩾ 32 weeks GA who had major surgery stayed in hospital about two weeks longer than infants of similar gestations who received assisted ventilation but not surgery. Antenatal diagnosis of congenital malformations has contributed to the improved prognosis of infants undergoing neonatal surgery,[56] and in this study, an antenatal diagnosis of a fetal malformation was made in nearly half of the infants receiving surgery.

There was an increasing use of CPAP over the two year period. Some 76% of infants of ⩾ 32 weeks GA who had assisted ventilation but not major surgery received CPAP only, compared with 6% for infants who had major surgery. A Northern Californian population reported a much larger proportion of infants at 32 weeks GA or more receiving IPPV only.[42] However, the duration of assisted ventilation for both populations was similar, reporting a positively skewed duration of ventilation at < 32 weeks GA, and a median of two days of assisted ventilation for infants born at ⩾ 32 weeks GA.

These population based national data will be beneficial to carers, parents, health service planners, health workers, and researchers. They will assist with quality improvement, highlighting areas where efficiency can be improved, allocating health resources, and in the planning of appropriate educational, community, and health services for these infants and their families. Data from the ANZNN serve as a basis for future research, including identifying variations in practice and outcomes after adjusting for risk,[57] determining risk factors for morbidity and mortality, and in the planning of clinical trials.

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Archimedes

In order to give the best care to patients and families, paediatricians need to integrate the highest quality scientific evidence with clinical expertise and the opinions of the family. *Archimedes* is a bimonthly section in *Archives* which seeks to assist practising clinicians by providing "evidence based" answers to common questions which are not at the forefront of research but are at the core of practice.

The format of *Archimedes* may be familiar. A description of the clinical setting is followed by a structured clinical question and a brief report of the search. The best evidence available to answer the question is provided as a summary table (which is electronically linked to more detailed appraisals). To pull the information together, a commentary follows. Finally, to make it all much more accessible, a box provides the clinical bottom line.

This month the following topics have been published which may be of interest to neonatologists:

- Likelihood ratios
- Should we glue lip lacerations in children?
- Is nebulised tolazoline an effective treatment for persistent pulmonary hypertension (PPH) of the newborn?
- How good is clinical examination at detecting a significant patent ductus arteriosus in the preterm neonate?

Previous *Archimedes* questions can be found in the issues of *Archives* published in the *Fetal and Neonatal edition* months since September 2001. Readers wishing to submit their own questions—with best evidence answers—are encouraged to read the Instructions for Authors at http://www.archdischild.com.