Changing availability of neonatal intensive care for extremely low birthweight infants in Victoria over two decades

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Neonatal intensive care, like all healthcare programs, should be evaluated to determine its effectiveness, efficiency and availability.[1] For the state of Victoria, we have established that neonatal intensive care for extremely low birthweight (ELBW) infants (birthweight < 1000 g) has been both increasingly effective[2] and relatively efficient[3] over the period 1979 to 1997. The final step was to determine whether neonatal intensive care is available to the infants who may benefit from it.[1] Availability reflects a balance between the resources provided to care for ELBW infants and decision-making by parents and healthcare providers about the appropriateness of providing intensive care.

In this study, we sought to evaluate the changes in availability of neonatal intensive care for ELBW infants in Victoria between 1979 and 1997, and the consequences of those changes for ELBW infants.

ABSTRACT

Objective: To determine the changes in availability of neonatal intensive care for extremely low birthweight (ELBW) infants, and the consequences of a lack of availability.

Design and setting: Population-based cohort study of consecutive ELBW infants born in the state of Victoria during four distinct eras.

Participants: All livebirths weighing 500–999 g in Victoria in the calendar years 1979–1980 ($n = 351$), 1985–1987 ($n = 560$), 1991–1992 ($n = 429$), and 1997 ($n = 233$).

Main outcome measures: Changes over time in the proportions of ELBW infants offered intensive care, the proportions that were "outborn" (born outside level 3 perinatal centres), and their survival rates and quality of survival compared with "inborn" infants.

Results: The proportions of ELBW infants offered intensive care increased over time and were significantly higher in heavier infants. The proportion of outborn ELBW infants was 30% in 1979–1980, falling to 9% by 1997. The difference in survival rates between inborn and outborn infants widened progressively over time: the survival advantages for inborn infants over outborn infants were 12.0% in 1979–1980, 30.1% in 1985–1987, 36.5% in 1991–1992, and 43.6% in 1997. For survivors, the quality of life was significantly better for inborn infants in two of the four eras.

Conclusions: Neonatal intensive care has been increasingly available for ELBW infants in Victoria over the period 1979 to 1997. The gap in survival rates between outborn and inborn infants has widened, and the quality of life of outborn survivors is inferior.

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METHODS

Cohorts

The ELBW babies comprised consecutive livebirths of birthweight 500–999 g born in Victoria during four distinct periods ("eras"): 1979–1980, 1985–1987, 1991–1992 and 1997. The multiple data sources used (level 3 [high-risk] perinatal centres, the Newborn Emergency Transport Service, and the Victorian Perinatal Data Collection Unit) and the methods for obtaining the total number of livebirths have been described previously.[4] ELBW infants were referred to as "inborn" if they were born in a level 3 perinatal centre and "outborn" if not.

Controls comprised randomly selected normal birthweight (NBW) livebirths (birthweight > 2499 g) for the first, third and fourth ELBW cohorts. The first NBW cohort was born in 1981–1982 in one of the three level 3 perinatal hospitals in Victoria. The other two NBW cohorts were derived from each of the three level 3 perinatal centres, matched with the ELBW survivors from the respective centres for the mother's health insurance status, language spoken primarily in the mother's country of birth (English or other), and the ELBW child's sex and expected date of birth.

Disability assessment

The survival rate was determined at 2 years of age (corrected for prematurity, where appropriate). The paediatricians and psychologists carrying out the 2-year assessment of survivors were blinded to the perinatal details. Impairments among the survivors included cerebral palsy, blindness (diagnosed by paediatric ophthalmologists during the first 2 years of life), deafness (requiring hearing aids) and developmental delay. Criteria for the diagnosis of cerebral palsy included loss of motor function combined with abnormalities of tone and reflexes.[5] The first three ELBW cohorts were assessed psychologically by the Mental Developmental Index (MDI) of the original Bayley scales of infant development,[6] whereas the last cohort was assessed using the revised Bayley scales.[7] A developmental quotient (DQ) for each ELBW child was calculated as DQ = (child's MDI – mean MDI for NBW controls) / SD.

Developmental delay was defined as having a DQ < –1 SD. The mean MDI on the original Bayley scales for the first (1981–1982) cohort of NBW controls was 105.8, and rose to 114.9 for the second (1991–1992) NBW cohort. A target mean MDI of 110 (SD, 16) was assumed for the second ELBW cohort to be an approximate mid-

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1 Proportion of ELBW infants offered intensive care, and their survival rate at 2 years, by birthweight group and birth era

Birth era	Proportion of all infants offered intensive care	Proportion of inborn* infants offered intensive care	Survival rate of infants offered intensive care
500–999 g birthweight (total group)			
1979–1980	57.5% (202/351)	66.9% (164/245)	44.1% (89/202)
1985–1987	70.2% (393/560)	79.8% (344/431)	53.9% (212/393)
1991–1992	81.6% (350/429)	89.0% (322/362)	68.9% (241/350)
1997	89.7% (209/233)†	92.9% (197/212)†	81.3% (170/209)†
500–749 g birthweight subgroup			
1979–1980	28.7% (37/129)	35.6% (32/90)	21.6% (8/37)
1985–1987	45.7% (102/223)	56.6% (86/152)	20.6% (21/102)
1991–1992	59.2% (100/169)	73.5% (97/132)	54.0% (54/100)
1997	81.5% (88/108)†	87.5% (84/96)†	75.0% (66/88)†
750–999 g birthweight subgroup			
1979–1980	74.3% (165/222)	85.2% (132/155)	49.1% (81/165)
1985–1987	86.4% (291/337)	92.5% (258/279)	65.6% (191/291)
1991–1992	96.2% (250/260)	97.8% (225/230)	74.8% (187/250)
1997	96.8% (121/125)†	97.4% (113/116)†	86.0% (104/121)†

ELBW = extremely low birthweight. * Inborn infants are those born in a level 3 perinatal centre.
† Statistically significant increase over time by χ^2 test for trend within birthweight subgroup.

point between the first two NBW cohorts. Children unable to complete psychological testing because of presumed severe developmental delay were assigned a DQ < –3 SD.

Severe neurosensory disability was defined as severe cerebral palsy (child unlikely ever to walk), blindness, or a DQ < –3 SD; moderate disability was defined as moderate cerebral palsy (child not walking at 2 years but expected to do so eventually), deafness, or a DQ between –3 SD and < –2 SD; mild disability was defined as mild cerebral palsy (child walking at 2 years), or a DQ between –2 SD and < –1 SD. The remaining children were considered to have no disability. For ELBW children from the first three cohorts who were not assessed at 2 years but were assessed later in childhood, disabilities were classified according to similar criteria, except that intelligence quotient scores were used instead of the MDI. The few ELBW survivors not assessed at any age (n = 6) were assumed to be non-disabled.

Utilities

Utilities (weights used to adjust survival for quality of life) for survivors were assigned, as described previously,[8] according to the severity of the disability: 0.4 for severe, 0.6 for moderate, 0.8 for mild, and 1 for no disability. Infants who died were assigned a utility of 0. Utilities were multiplied for children with multiple disabilities. The utilities were summed, divided by the number of livebirths, and multiplied by 100 to calculate the quality-adjusted survival rate.

Availability of intensive care

The proportions of infants offered intensive care, and whether they were inborn or outborn, were recorded for all ELBW infants. Infants offered intensive care included all those given assisted ventilation by endotracheal tube (including those who died in the delivery room after such care and all survivors, whether cared for in a level 3 nursery or not). Availability of neonatal intensive care was determined, firstly, by the proportion of infants offered intensive care, and, secondly, by the proportion of outborn infants (in that it reflects decision-making before birth).

Over the four eras, we compared outborn with inborn infants with regard to the proportion who were offered intensive care, the proportion who were outborn versus inborn, their survival rates and quality-adjusted survival rates, and the quality of life of survivors.

Statistical analysis

Data were analysed by SPSS for Windows software.[9] Survival rates of outborn versus inborn infants were compared by calculating the difference between proportions of survivors.[10] Differences between proportions with increasing birthweight were determined by a χ^2 test for trend. Differences between eras in ordered categories and for quality-adjusted survival rates were compared by a Mann–Whitney U test.[11] Data between eras were contrasted overall and within two birthweight subgroups (500–749 g and 750–999 g).

Ethics approval

Our study was approved by the Research and Ethics Committee of the Royal Women's Hospital.

RESULTS

The numbers of livebirths of ELBW infants in each era were 351, 560, 429 and 233, respectively. The proportion of infants offered intensive care rose significantly over time, in each birthweight subgroup and among both inborn infants and all infants (Box 1). The survival rates to 2 years of age for those offered intensive care were higher in each successive era, both overall and in each birthweight subgroup (Box 1).

2 Proportion of outborn* ELBW livebirths, by birthweight group and birth era

Birth era	Proportion of infants outborn*
500–999 g birthweight (total group)	
1979–1980	30.2% (106/351)
1985–1987	23.0% (129/560)
1991–1992	15.6% (67/429)
1997	9.0% (21/233)†
500–749 g birthweight subgroup	
1979–1980	30.2% (39/129)
1985–1987	31.8% (71/223)
1991–1992	21.9% (37/169)
1997	11.1% (12/108)†
750–999 g birthweight subgroup	
1979–1980	30.2% (67/222)
1985–1987	17.2% (58/337)
1991–1992	11.5% (30/260)
1997	7.2% (9/125)†

ELBW = extremely low birthweight. * Outborn infants are those born outside level 3 perinatal centres. † Statistically significant decrease over time by χ^2 test for trend within birthweight subgroup.

3 Survival rates at 2 years of outborn v inborn* ELBW infants, by birthweight group and birth era

Birth era	Survival rate of outborn infants	Survival rate of inborn infants	Difference in survival rate for outborn v inborn infants (95% CI)
500–999 g birthweight (total group)			
1979–1980	17.0% (18/106)	29.0% (71/245)	–12.0% (–20.4%, –2.2%)
1985–1987	14.7% (19/129)	44.8% (193/431)	–30.1% (–37.0%, –21.5%)
1991–1992	25.4% (17/67)	61.9% (224/362)	–36.5% (–46.6%, –23.9%)
1997	33.3% (7/21)	76.9% (163/212)	–43.6% (–60.5%, –21.4%)
500–749 g birthweight subgroup			
1979–1980	2.6% (1/39)	7.8% (7/90)	–5.2% (–12.9%, 6.1%) (ns)
1985–1987	2.8% (2/71)	12.5% (19/152)	–9.7% (–16.2%, –1.5%)
1991–1992	2.7% (1/37)	40.2% (53/132)	–37.4% (–46.3%, –23.8%)
1997	16.7% (2/12)	66.7% (64/96)	–50.0% (–64.8%, –20.2%)
750–999 g birthweight subgroup			
1979–1980	25.4% (17/67)	41.3% (64/155)	–15.9% (–27.8%, –2.2%)
1985–1987	29.3% (17/58)	62.4% (174/279)	–33.1% (–44.6%, –19.1%)
1991–1992	53.3% (16/30)	74.3% (171/230)	–21.0% (–39.0%, –3.5%)
1997	55.6% (5/9)	85.3% (99/116)	–29.8% (–59.2%, –3.1%)

ELBW = extremely low birthweight. ns = not significant. * Inborn and outborn infants, respectively, are those born in or outside a level 3 perinatal centre.

In the first era, about 30% of ELBW infants were outborn and the proportions were similar across both birthweight subgroups (Box 2). Overall, the outborn proportion decreased by about 7% (absolute) in each successive era, falling to 9% by the last era. Within the 750–999 g birthweight subgroup (over the four eras) and the 500–749 g birthweight subgroup (over the last three eras), there was a steady decline in the proportion of outborn infants (Box 2). Within both birthweight subgroups the fall in the outborn proportion over time was statistically significant.

Compared with inborn infants, the survival rate to 2 years of age was significantly lower in outborn infants, and the absolute difference in survival rates between the groups progressively widened over time for ELBW infants as a whole (birthweight 500–999 g) (Box 3). A similar pattern was noted within birthweight subgroups, although not all subgroup differences were statistically significant (Box 3). There was only one outborn survivor, born in the 1985–1987 era, who was not transferred after birth for care in a level 3 centre during his primary hospitalisation.

Among survivors alone, outborn infants had significantly lower quality of life than inborn infants in the first and last eras, but not the middle eras, despite the small number of outborn survivors in each era (Box 4). No statistical conclusions were altered if utilities for the six survivors not assessed were assumed to be 0 rather than 1.

The quality-adjusted survival rates were significantly lower in outborn infants in all eras, and the difference between inborn and outborn infants widened progressively over time (Box 5). Within both birthweight subgroups the quality-adjusted survival rates were inferior in outborn infants, although not all differences were statistically significant.

DISCUSSION

In Victoria, an increasing proportion of ELBW infants have been offered intensive care over the years between 1979 and 1997. The proportion of ELBW infants offered intensive care in the latest era was 90% overall, 93% for inborn infants and close to 100% for the heaviest infants. Over the same period, there has been a progressive fall in the proportion of outborn ELBW infants to less than 10% in the latest era, accompanied by an increasing survival rate and quality-of-survival advantage for inborn infants compared with outborn infants. This emphasises the need for ELBW infants in Victoria to be born in level 3 perinatal centres, if at all possible.

A weakness of our study was that we did not have accurate data on the circumstances of birth or gestational ages for all outborn infants in each era. Hence, it was not possible to determine how many more outborn infants in each era might have been safely transferable *in utero* to a level 3 perinatal centre.

There have been several recent US studies on the differential outcome between ELBW infants born within level 3 perinatal centres and those born outside such centres.[12-14] In common with an earlier study from our region,[15] these studies have shown that the number of ELBW infants born in level 3 perinatal centres has increased over the past two decades and that survival rates are better for inborn infants than outborn infants, with the survival difference progressively widening. These studies, supported by our findings, suggest that one way to improve survival rates of ELBW infants is to increase the proportion who are born within level 3 perinatal centres and thus have ready access to intensive care facilities if needed. However, not all studies have reported better survival rates for inborn infants[16] or a widening survival advantage for inborn infants over time.[17]

While the proportion of outborn ELBW infants in Victoria has fallen steadily over the

4 ELBW infants: median utility score* for survivors, by outborn v inborn status† and birth era

Birth era	Utilities per survivor (median [interquartile range]): Outborn infants	Inborn infants	Mann–Whitney *U* test
1979–1980	0.62 (0.36, 0.85) (n = 18)	0.80 (0.64, 1.00) (n = 71)	$Z = 2.7$, $P < 0.01$
1985–1987	1.00 (0.80, 1.00) (n = 19)	1.00 (0.80, 1.00) (n = 193)	$Z = 0.53$, $P = 0.60$‡
1991–1992	1.00 (0.80, 1.00) (n = 17)	1.00 (0.80, 1.00) (n = 224)§	$Z = 0.53$, $P = 0.60$‡
1997	0.60 (0.48, 0.80) (n = 7)	1.00 (0.80, 1.00) (n = 163)§	$Z = 2.2$, $P = 0.03$

ELBW = extremely low birthweight. * Utilities are weights used to adjust survival for quality of life. † Inborn and outborn infants, respectively, are those born in or outside a level 3 perinatal centre. ‡ Not significant at 5% level. § Assumes infants not seen had utility of 1.

5 Quality-adjusted survival rates of outborn v inborn* ELBW infants, by birthweight group and birth era

Birth era	Quality-adjusted survival rate: Outborn infants	Inborn infants
500–999 g birthweight (total group)		
1979–1980	10.0%	23.4%†
1985–1987	12.8%	37.5%†
1991–1992	21.2%	52.1%†
1997	20.8%	62.6%†
500–749 g birthweight subgroup		
1979–1980	1.0%	5.1%
1985–1987	2.3%	10.9%†
1991–1992	2.7%	31.9%†
1997	8.3%	50.1%†
750–999 g birthweight subgroup		
1979–1980	15.3%	34.1%†
1985–1987	25.8%	52.0%†
1991–1992	44.1%	63.6%
1997	37.3%	73.0%†

ELBW = extremely low birthweight. * Inborn and outborn infants, respectively, are those born in or outside a level 3 perinatal centre. † Statistically significant difference between inborn and outborn infants by Mann–Whitney *U* test.

past 20 years and may drop even further, it will never fall to zero — there will always be some infants who are outborn, either because there is insufficient time to reach the centre before birth occurs, or because in-utero transfer is too hazardous for the mother or infant. Nevertheless, there is still a small margin for reducing the proportion of outborn infants.

It should also be borne in mind that some ELBW infants will not benefit from intensive care (eg, those who are extremely premature or who have lethal malformations). (We did not exclude such infants from our study.) Hence, we should not aim towards offering intensive care to all ELBW infants.

Since the late 1970s,[18,19] in Victoria, there has been an ongoing education program highlighting the benefits of in-utero referral for very preterm pregnancies. However, the message has only gradually filtered through to the community. The progressively decreasing proportion of outborn ELBW infants over time reflects predominantly obstetric decision-making. It is important that the message of the advantages of in-utero referral for ELBW infants reaches all those involved in obstetric decision-making — not only obstetricians, but also other health personnel such as general practitioners and nurses, as well as the parents of the infants concerned. Paediatricians also have a role in reporting outcomes, as well as in discussing management of high-risk pregnancies with their obstetric colleagues.

Sinclair et al,[1] in their 1981 article on the evaluation of neonatal intensive care programs, indicated there was no firm evidence that the use of neonatal intensive care services reflected the *need* for those services. They even suggested that the use of neonatal intensive care might be determined by supply rather than need. We would suggest that the dramatically improving survival and quality-adjusted survival rates for ELBW infants in Victoria over two decades[2] strongly support the case for an increasing need for neonatal services in our state. Moreover, such care can be provided relatively efficiently.[3] As most ELBW infants now survive, the remaining major challenge is to improve the quality of life of survivors. One way for us to achieve this will be to try to reduce the outborn proportion below the already low rate.

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REFERENCES

1 Sinclair JC, Torrance GW, Boyle MH, et al. Evaluation of neonatal intensive-care programs. *N Engl J Med* 1981; 305: 489-494.
2 Doyle LW, for the Victorian Infant Collaborative Study Group. Evaluation of neonatal intensive care for extremely low birthweight infants in Victoria over two decades: I. Effectiveness. *Pediatrics* 2004; 113: 505-509.
3 Doyle LW, for the Victorian Infant Collaborative Study Group. Evaluation of neonatal intensive care for extremely low birthweight infants in Victoria over two decades: II. Efficiency. *Pediatrics* 2004; 113: 510-514.
4 Doyle LW, Kitchen WH, Lumley J, et al. Accuracy of mortality rates for livebirths 500–999 g birthweight. *Med J Aust* 1992; 156: 72.
5 Kitchen WH, Doyle LW, Ford GW, et al. Changing two-year outcome of infants weighing 500 to 999 grams at birth: a hospital study. *J Pediatr* 1991; 118: 938-943.
6 Bayley N. Bayley scales of infant development. New York: The Psychological Corporation, 1969.
7 Bayley N. Bayley scales of infant development. 2nd ed. San Antonio: The Psychological Corporation, 1993.
8 Victorian Infant Collaborative Study Group. Economic outcome for intensive care of infants of birthweight 500–999 g born in Victoria in the post surfactant era. *J Paediatr Child Health* 1997; 33: 202-208.
9 SPSS for Windows Version 11.0.1 [computer program]. Chicago, Ill: SPSS Inc., 2001.
10 Altman DG, Machin D, Bryant TN, Gardner MJ. Statistics with confidence. London: BMJ Books, 2000.
11 Moses LE, Emerson JD, Hosseini H. Analyzing data from ordered categories. *N Engl J Med* 1984; 311: 442-448.
12 Powell SL, Holt VL, Hickok DE, et al. Recent changes in delivery site of low-birth-weight infants in Washington: impact on birth weight-specific mortality. *Am J Obstet Gynecol* 1995; 173: 1585-1592.
13 Yeast JD, Poskin M, Stockbauer JW, Shaffer S. Changing patterns in regionalization of perinatal care and the impact on neonatal mortality. *Am J Obstet Gynecol* 1998; 178: 131-135.
14 Bode MM, O'Shea TM, Metzguer KR, Stiles AD. Perinatal regionalization and neonatal mortality in North Carolina, 1968–1994. *Am J Obstet Gynecol* 2001; 184: 1302-1307.
15 Victorian Infant Collaborative Study Group. Changing outcome for infants of birth-weight 500–999 g born outside level 3 centres in Victoria. *Aust N Z J Obstet Gynaecol* 1997; 37: 253-257.
16 Verloove-Vanhorick SP, Verwey RA, Ebeling MC, et al. Mortality in very preterm and very low birth weight infants according to place of birth and level of care: results of a national collaborative survey of preterm and very low birth weight infants in The Netherlands. *Pediatrics* 1988; 81: 404-411.
17 Saigal S, Rosenbaum P, Hattersley B, Milner R. Decreased disability rate among 3-year-old survivors weighing 501 to 1000 grams at birth and born to residents of a geographically defined region from 1981 to 1984 compared with 1977 to 1980. *J Pediatr* 1989; 114: 839-846.
18 Consultative Council on Maternal and Perinatal Mortality. Annual report for the year 1977. Melbourne: Health Commission of Victoria, 1978.
19 Kitchen WH, Campbell N, Drew JH, et al. Provision of perinatal services and survival of extremely low birthweight infants in Victoria. *Med J Aust* 1983; 2: 314-318.

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