Supplementary Material 1

Literature Review on Neonatal mortality

Our literature review summarised twenty-four papers that estimated the mortality of neonatal infants. The research showed a large difference between studies in terms of population, characteristics, outcomes, hospital type and unit. The studies consider very pre-term infants, [1-8] analysed births with less than 32 weeks of gestational age, with some [9, 10] focusing on less than 30 and 29 weeks of gestational age, and others [11-13] on less than 28 weeks of gestational age. Only one paper [14] included extremely preterm infants (25 weeks of gestational age) while seven studies did not report in detail the gestational age [15-21].

The impact of unit volume in neonatal care and mortality was discussed by nine studies [4, 6, 16, 17, 19, 21-24]. In these studies, most used Logistic regression to estimate the outcome, and three used an instrumental variable approach [4, 23, 25].

The availability of staff in a unit can influence the mortality in neonatal mortality, but only four [4, 6, 16, 23] of overall studies considered the staff availability of nurse, consultants or both in the mortality model.

Table 1 below summarises the studies considered and reports information on: Country, Gestational age, Birthweight, Population, Outcomes, Unit type, Volume, Data, Nursing/Staff, Costs, Hospital type, Methods, Other, Covariates.

Table 1: Literature review on neonatal mortality

#	Paper	Year	Country	Gest. age	Birthweight (gr)	Population	Outcomes	Unit type	Volume	Data (year)	Nursing / Staff	Costs	Hospital type	Methods	Other	Covariates
1	Tucker et al. UK neonatal staffing study[26]	2002	UK	Not rep	<1500	13401	Neonatal mortality Major cerebral abnormality Nosocomial bacteraemia	NICU	High (>58), Medium (35-57), Low (<35)	1996-2000	Consultant availability and nursing provision	Yes	No	Generalised estimating equations models	Relation of outcomes in NICUs with respect to volume, staffing and workload Nurse co ratio (<0.84,>=0.84) Consultant availability (higher >=2, lower<2)	Consultant availability, Nurse provision, Infants, Unit, Birthweight, Gestation weeks
2	Gale et al.[22]	2012	England	27-28.5	<500, 500-999, 1000-1499, 1500-1999, >2000	CESDI project and NDAU data	Proportion of births in HV neonatal care, IC days, Acute and late postnatal transfer, Multiple and singleton births that had transfers before 28 days, Neonatal survivals at 28 days, Transfers at 24 hours after birth, neonatal unit designation(level) and neonatal intensive care activity of hospital of birth	all	IC days (>2000 and <2000)	2 epochs; 1998-2000, 2009-2010 from NDAU	No	No	Not reported	Logistic regression	Evaluation of two different epochs	Individual patient level data on hospital of birth, gestational age, birth weight, sex, multiple birth, transfers, encrypted maternal NHS number, admission, and discharge times for each hospital episode, daily level of care, and survival for babies born at 27-28 weeks' gestation
3	Johansson et al.[1]	2004	Sweden	24-31	Not rep	2253 Singleton infants	Infant mortality	No	Not reported	1992-1998	No	No	University - General	Not clear	Antenatal maternal characteristics (illness, diabetes, hypertension, chronic diseases	
4	Evans et al. [4]	2007	Australia and New Zealand	<32	<1500	5713	Infant mortality	NICU	Not reported	1998-2001	No	No	Not reported	Multivariate Logistic regression model		
5	Cole et al.[3]	2010	England	22-31	<2400	1456	Survival to term		Not reported	2000-2004	No	No		Logistic regression		Sex, Gestation days, gestation weeks completed, Birthweight z score, Birthweight prenatal estimate z-score, Base deficit(measure of acidosis), Stillborn, died before term
6	Ge et al.[9]	2013	Canada	23-30	Not rep	6106	Survival without morbidities Survival with mild morbidities Survival with severe morbidities Mortality	Level 3 (NICU)	Not reported	2010-2011	No	No		Multinomial Logistic regression		13: maternal factors (hypertension, smoking, illicit drug use), infant characteristics (GA, SGA, gender, score SNAPII>20, multiple birth, inborn or out born status, caesarean delivery), receipt of antenatal corticosteroids, receipt of surfactant and mechanical ventilation on day one in the NICU
7	Watson et al.[27]	2014	England	<33	Not rep		28 days mortality, any in-hospital mortality, surgery for necrotising enterocolitis treatment for retinopathy of prematurity (ROP) Bronchopulmonary dysplasia (BDP)	Level 3 (NICU) and High Volume NICU	High Volume considering the units with more than 100 VLBW (1500 gr) per year	2009-2011	No	No	Not reported	Instrumental variables		Gestational age at birth, gestational age squared, birthweight z-score (BW standardized by GA), antenatal steroids, sex, infant year of birth and the residence of the mother if it is in the lowest decile of IMD 2007 score
8	Watson et al [23]	2016	England	Not rep.	Not rep	173 units	Monthly in hospital intensive care rate.	Level 3 (NICU)	Yes, volume of unit as covariate	2008-2012	Yes Nurse to infant ratio	No	Not reported	Instrumental variables	IV one-to-one nursing ratio	Gestational age at birth, gestational age squared, birthweight z-score (BW standardized by GA), the monthly volume of neonatal unit (to capture nurse workload), antenatal steroids, sex, infant year and month of birth
9	Manktelow et al.[28]	2013	England	<33	Not rep	3065	Probability of survival	NICU	No	2008-2010	No	No	Not reported	Logistic regression		Gestational age in days, birthweight and gender
10	Hinchliffe et al.[11]	2013	England	24-28	Not rep	2723	Cause specific hazard for discharge In-unit neonatal death for all babies that were in neonatal care for the first 7 days of life	N.R.	No	2006-2010	No	No	Not reported	Flexible parametric survival model using restricted cubic splines		Gestational age at birth, gender, z-scores for birthweight
11	Cifuentes et al. [17]	2002	USA (California)	Not rep.	<2000	16732	Neonatal related mortality	NICU and other levels	The volume has a significant differences on mortality for the large units	1992-1993			Hospital without NICU, no Intensive Care, intermediate NICU, intermediate intensive care, community NICU, expanded intermediate intensive care, regional NICU	Risk adjusted mortality model based on logistic regression	Singleton infants Excluded infants with less than 500 gr of BW BW is infants with less than 2000 grams Considers different levels of care	Birthweight, gender maternal demographic factors, many clinical diagnoses
12	Rautava et al.[6]	2007	Finland	<32	<=1500	2291	One year mortality	Level II (central) and Level III (university) hospitals	The volume (university level) has a lower risk than central one	2000-2003	Indirectly (use office and non-office hours)	No	University and central hospital	Logistic regression	Evaluate the effect of birth in the two levels (Central and University hospital)	Hospital level, gestational age, birthweight, time of birth (office and non-office hours), gender, fetal growth, maternal smoke, maternal age, Parity, hypertension.

13	Phibbs et al.[18]	2007		Not rep	<1500	66838	Neonatal mortality (28 days after birth)	Different levels of NICU	Estimates the effect of the volume of units with the mortality OR	1991-2000	No	No	No	Logistic regression Regression run separately for each level of care	Shows the effect of volume of VLBW infants varies between NICU levels Singletons	Birthweight, gestational age, clinical and demographic variables from the birth certificate and discharge data to control risk factors
14	Rogowski et al. [19]	2004	USA (Vermont)	Not rep	500-1500 VLBW	94110	Mortality among VLBW infants prior to discharge at home	NICU(3 levels of NICU)	Volume of infants	1995-2000	No	No		Logistic regression		Gestational age in weeks and its square, small for GA (birthweight of less than the 10th percentile for gestational age based on sex), 1-minute APGAR score, race, sex, multiple birth, presence of a major birth defect, vaginal delivery, any prenatal care received by the mother
15	Lee et al.[14]	2010	USA (California)	22-25	401-1000	4527	Death before discharge from the hospital	NICU	No	2005-2008	No	No	No	Logistic mixed model	highly specialized group of NICUs	birth weight, estimated GA, sex, prenatal steroid exposure, and multiple birth, Race/ethnicity
16	Ruegger et al.[7]	2012	Switzerland	<32	<1500	3090	Neonatal mortality rate, Morbidities (BDP, NEC, IVH, PVL, PDA, RDS, ROP, Sepsis)	NICU, NU, Neuropediatric centres	No	1996,2000, 2004, 2008	No	No	No	Statistical analysis to compare the outcomes (mortality and morbidities) in 12 years observation	The study evaluates the trend in mortality, morbidities and treatment for VPT and VLBW infants over 12	Gender, Location of birth (inborn,outborn), Mode of delivery, Number of infants, gestational age, Birthweight
17	Shah et al. [10]	2012	Canada	<29	Not rep	1897,1866	Death in the NICU, BDP, Severe IVH, Severe ROP, PDA and NEC	NICU	No	1996-1997, 2006-2007	No	No	No	Multivariate logistic regression	Comparison of data over 10 years	Gestational age, Small for Gestational age, Score of Neonatal Acute Physiology (SNAP), Apgar score, Birthweight, Delivery type, Maternal Hypertension, Presentation (Vertex, Breech, other), Antenatal steroids use, Prenatal care, Multiple births
18	Fanaroff et al.[20]	2007	USA	Not rep	201-1500		Neonatal mortality Morbidities	Not Reported	No	1990-1991, 1995-1996, 1997-2002	No	No	No	Logistic regression	Comparison of data over three different periods	Birthweight, gestational age, sex
19	Stoll et al.[13]	2015	USA	22-28	401-1500	34636	Changes over time in maternal and neonatal practices Neonatal mortality Neonatal morbidities	Not Reported	No	1993-2012	No	No	No	Linear and Logistic regressions	Trend in care analysis	Gestational age, small for Gestational age, Birthweight, maternal age, race, ethnicity, prenatal care, insulin-dependent diabetes, hypertension, multiple birth, birth defects, antenatal steroids, caesarean delivery, delivery room resuscitation, surfactant therapy, postnatal steroids, respiratory support.
20	Express group, Fellman et al. [29]	2009	Sweden	<27	<1500	1011	One-year survival of infants	No	No	2004-2007	No	No	Level III hospital	Logistic regression		Gestational age, use of tocolytic treatment, antenatal corticosteroids, surfactant treatment within 2 hours from birth, birth at level III hospital, sex
21	Stoll et al. [12]	2010	USA	22-28	401-1500	9575	Neonatal mortality Neonatal morbidities	No	No	2003-2007	No	No		Logistic regression Robust Poisson regression	Analysis of change	Gestational age
22	Lasswell et al. [8]	2010	USA	<32	<1500	(Meta-analysis)	Neonatal mortality	Level III and non-Level III	No	1976-2010	No	No	Different levels of hospitals (III level and non-III level)	Not clear	Meta-analysis on regionalization of perinatal services for VPT or VLBW infants	Association between of level of hospital and VLBW
23	Lorch et al.[25]	2012	USA	23-37	Not rep	1328132	In-hospital mortality Complications of premature births	High Level NICU	No	1995-2003	No	No	Level III (at least 50 VLBW on average per year)	Instrumental variables	Instruments: difference in travel times from the mother's residential zip code to the nearest high level NICU and the mother's residence to the nearest other delivery hospital	Gestational age, birthweight, maternal sociodemographic factors (race, age, education, insurance status), maternal residential zip code sociodemographic information (percentage of inhabitants living below the US federal poverty line), maternal comorbid condition, 49 congenital anomalies grouped by affected organ system
24	UK neonatal staffing study[21]	2001	UK	Not rep	<1500	13401	Neonatal mortality Major cerebral abnormality Nosocomial bacteraemia	NICU	High (>58), Medium (35-57), Low (<35)	1996-2000	Consultant availability and nursing provision	Yes	No	Logistic regression	Relation of outcomes in NICUs with respect to volume, staffing and workload Nurse co ratio (<0.84,>=0.84) Consultant availability (higher >=2, lower<2)	Birthweight, gestational age, mode of delivery, gender, antenatal steroids, infant temperature, surfactant therapy, oxygen therapy, blood gas measures in the first 12 hours

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