Chapter 6

Factors Associated with Survival to Discharge of Newborns in a Middle-Income Country

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Additional information is available at the end of the chapter

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Abstract

Clinical and mortality audit is an essential part of quality improvement in health care; information obtained in this process is used to develop targeted interventions to improve outcome. This study aimed to determine predictors of short-term survival in neonates. An existing neonatal database was reviewed. A total of 5018 neonates > 400 g admitted to a tertiary hospital (Johannesburg South Africa) between 1 January 2013 and 31 December 2015 were analysed. Mean birth weight was 2148 g (standard deviation [SD]: 972) and mean gestational age was 34.2 weeks (SD: 4.8). Overall survival was 85.6% (4294/5018). The most common causes of death were prematurity (46.2%), hypoxia (19.5%) and infection (17.2). The strongest predictors of survival were birth weight (OR 1.0; 95% confidence intervals (CI): 1.0–1.01) and gestational age (OR = 1.1, 95% CI: 1.05–1.17). Other predictors of survival included metabolic acidosis (OR = 0.14, 95% CI: 0.09–0.20), hyperglycemia (OR = 0.31, 95% CI: 0.23–0.41), mechanical ventilation (OR = 0.35, 95% CI: 0.28–0.46), major birth defect (OR = 0.12, 95% CI: 0.08–0.18), resuscitation at birth (OR = 0.39, 95% CI: 0.31–0.49) and Caesarean section (OR = 1.8, 95% CI: 1.44–2.25). In conclusion, resources need to be focused on improved care of VLBW infants.

Keywords: neonatal mortality, clinical audit, very low birth weight, premature infants

1. Introduction

The fourth Millennium Development Goal (MDG) was a two-third reduction in the mortality of children under the age of 5 years, which sub-Sahara African countries (including South Africa) failed to achieve this [1]. In 2015, 1 million children died within the first day of life, a further million in the first week of life and yet another 2.8 million in the first 28 days of life –

4.8 million of the almost 6 million children under the age of five years who died in 2015, died within the neonatal period [1]. Concentrating resources on newborns is therefore essential to further reduce childhood mortality.

The causes of neonatal mortality vary considerably among different units and different countries. The United Nations MDG 2015 report [1] states that "better data are needed for the post-2015 development agenda" and "real-time data are needed" to guide policy makers. Most data have a time lag of between 2 and 3 years before the policies are implemented. The MDGs formed the foundation of the so-called Sustainable Development Goals (SDG) [2]. The SDGs are less specific than the MDGs, but include health targets, one of which is to reduce both neonatal mortality and mortality of children under the age of 5 years.

Regular audits of neonatal mortality are required to identify the causes of death so that proper interventions can be implemented to reduce neonatal deaths. It is essential to have local data to address local health issues; transposing mortality data from another country will not necessarily solve local problems. This is particularly true when using data from a high-income country to address problems experienced in low- to middle-income countries (LMICS). A recent review of the mortality rates in neonatal intensive care units showed that the rate varied considerably between different countries [3]; the mortality rate was generally high, but greater in developing than developed countries. Issues such as the lack of antenatal care and inadequate health facilities are the causes of neonatal mortality in LMICS. A recent review from The Gambia [4] showed a high neonatal mortality rate – 35% of admitted neonates died. The important causes of neonatal death included lack of antenatal care, birth weight below 1500 g, hypothermia at birth, and delivery outside a teaching hospital.

Previous studies done in very low birth weight (VLBW) neonates – birth weight below 1500 g – at Charlotte Maxeke Johannesburg Academic Hospital (CMJAH) have shown that birth weight was the most significant predictor of survival [5, 6]. Resuscitation at birth, the use of nasal continuous positive airways pressure (NCPAP) and the mode of delivery were also important factors affecting survival. Survival of extremely low birth weight (ELBW) neonates was particularly low at CMJAH [7]. The provision of NCPAP to this category of neonates more than doubled their survival to discharge [6].

2. Determinants of neonatal survival at a tertiary hospital in Johannesburg, South Africa

Although VLBW mortality at CMJAH has been studied, the overall neonatal survival has not been audited. The aim of this study is to review neonatal survival at CMJAH and to determine important modifiable factors to inform protocols and budgeting for neonatal care. The objectives of this study were to:

- Describe the patient population with regard to demographic information, clinical characteristics, and outcome at discharge.

- Determine the survival rate for different birth weight categories.
- Establish factors associated with neonatal survival.

2.1. Subjects and methods

The study was conducted in the neonatal unit of a tertiary academic hospital (CMJAH) in Johannesburg, South Africa. All neonates admitted within 48 h of birth, between 1 January 2013 and 31 December 2015, were included in the study. Neonates with a birth weight below 400 g and those with important missing data, particularly birth weight, gestational age, and outcome at discharge were excluded.

2.2. Study design

This was a secondary analysis of an existing neonatal database. Data were collected upon discharge for each neonate admitted to the CMJAH neonatal unit and entered on to a database. The database was managed using Research Electronic Data Capture (REDCAP) [8] hosted by the University of the Witwatersrand. The information collected included demographic details, maternal information, delivery room data, clinical information, and outcome at discharge. Data from VLBW neonates was contributed to the Vermont Oxford Network (VON) (www.vtoxford.org), a multinational neonatal collaboration. A paper computer summary form was completed for each patient, using the patient file. Data were checked against the patient file and then entered on to the database. The information on the database was then checked against the paper form. Any discrepancies noted were verified against the patient files. Definitions and codes for congenital defects or surgical procedures were obtained from the VON.

Neonates were classified by weight using standard definitions—term large for gestational age (TLGA) neonates weighed above 4000 g at birth, term appropriate for gestational age (TAGA) infants weighed between 2500 and 3999 g at birth, low birth weight (LBW) neonates had a birth weight less than 2500 g, very low birth weight (VLBW) included those weighing less than 1500 g at birth and extremely low birth weight (ELBW) less than 1000 g at birth. Term was considered to be a gestation age between 37 and 42 weeks, preterm below 37 weeks, and post-term to be above 42 weeks.

The unit participated in a national perinatal mortality audit – the perinatal problem identification programme (PPIP)(www.ppip.co.za). The broad causes of neonatal death were categorized using standard PPIP definitions.

2.2.1. Neonatal unit

The neonatal unit was situated in large tertiary academic hospital in a metropolitan setting. Neonatal facilities included a transitional nursery in labour ward, a shared paediatric/neonatal intensive care unit (PNICU) with 15 ventilator beds, a neonatal high care unit with 40 beds, low-care facility with 25 beds, and nine kangaroo mother-care (KMC) beds. Nasal continuous positive airways pressure (NCPAP) and therapeutic hypothermia for perinatal asphyxia were provided in high care. The neonatal unit was staffed by neonatologists, registrars, and house staff. There were various paediatric sub-specialities in the hospital including nephrology, neurology, cardiology, endocrinology, and infectious diseases. There was a large paediatric surgery service and paediatric surgical neonates were admitted to the neonatal unit and jointly managed with the neonatal staff.

Neonates who were observed in the transitional unit and then discharged to their mothers were not included in the study. Neonates who died in the delivery room and transitional nursery were considered to be admissions and were included in the study. Owing to resource constraints, there were insufficient ventilator beds for the number of neonates requiring ventilation. The PNICU functioned essentially as a ventilator unit; high-care observation was not possible due to limited facilities. The neonatal unit had a policy of rationing care based on birth weight—babies weighing below 750 g at birth would not be offered surfactant or NCPAP, but only given supplemental oxygen, intravenous fluids, and antibiotics; babies weighing between 750 and 900 g would be given surfactant and NCPAP, but would not be provided with mechanical ventilation if required. All neonates with respiratory distress syndrome were initially managed with NCPAP and early rescue surfactant; those who failed would be transferred to the PNICU for mechanical ventilation. The use of NCPAP at CMJAH has recently been reviewed [9].

2.2.2. Statistical analysis

Data were exported to IBM SPSS version 22 for the purpose of analysis. The standard statistical methods were used to describe the data—continuous variables were described using measures of central tendency and dispersion, mean and standard deviation (SD), or median and interquartile range (IQR) as appropriate. Categorical variables were described using frequency and percentages.

The primary endpoint was whether a neonate survived to hospital discharge. Univariate analysis was done considering different maternal, demographic, and clinical variables as independent factors of survival. Differences in outcome for continuous variables were compared using unpaired *t*-tests or Mann Whitney *U*-test as appropriate. Associations of outcome with categorical variables were investigated using Chi-squared test. A factor with a *p*-value of 0.05 was considered statistically significant. Variables with a *p*-value <0.1 on the univariate analysis were entered into a multiple logistic regression model considering whether a child survived to discharge as the outcome variable. Factors associated with neonatal mortality were determined separately for VLBW and bigger babies.

The possible sources of bias were identified and excluded from the analysis. Conditions which were only present in neonates who were survivors and approaching discharge were identified and excluded from the analysis of deaths. These conditions included supplementary oxygen at 28 days, home oxygen and steroids for chronic lung disease. Maternal and delivery room conditions were compared between those neonates who died in the delivery room and those who died in the neonatal ward.

2.3. Ethics

Data were de-identified and the key to patient details was kept separately and only known to the principal investigator. Ethical clearance for the study was obtained from the Human Research Ethics Committee of the University of the Witwatersrand. Permission to conduct the study was obtained from the Chief Executive Officer of CMJAH. One of the authors was the gatekeeper of the neonatal database; additional permission to access the database was not required.

3. Results

The database was accessed on 20 February 2016, and there were 5695 neonatal records on the database; 5386 records were for neonates born within the study period. There were 26 records with missing outcome data, four babies who had a birth weight below 400 g and 338 neonates who were admitted to the unit after 48 h. Thus, 5018 records were included in the review. The mean birth weight was 2148 g (SD 972) and the mean gestational age was 34.2 weeks (SD 4.8). The mean duration of stay was 13.75 days (SD 18.0).

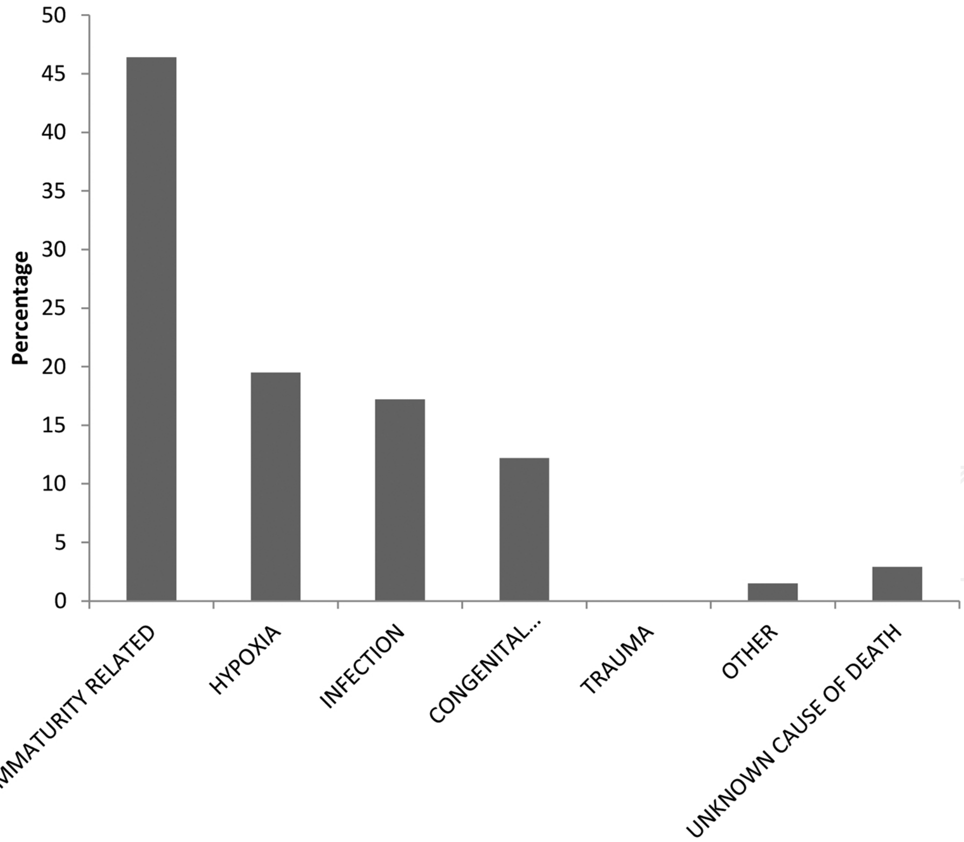

Figure 1. Causes of neonatal deaths in Johannesburg, South Africa, between 01 January 2013 and 31 December 2015.

There were 724 deaths, giving an overall mortality rate of 14.4%, alternatively expressed as a percentage surviving to discharge of 85.6. Seventy-three percent (530/724) of neonates died in the early neonatal period, within seven days of birth. There were 147 (20.3%) deaths in the delivery room and seventy neonates (9.6%) died within the first 12 hours of admission to the neonatal ward. The various causes of neonatal death according to the PPIP classification are shown in **Figure 1**.

3.1. Birth weight

The mortality rate was strongly associated with birth weight. There were 3134 LBW neonates, with a mortality rate of 18.6% (586/3134). The majority of deaths in LBW neonates occurred in VLBW neonates (30.1% (479/1590)). Significantly more VLBW neonates died than babies >1500 g (30.1% vs. 7.1%; $p < 0.001$). The number of neonates and those who died in each birth weight category is shown in **Table 1**.

Birth weight (g)	Number	Died	% Mortality
<1000 (ELBW)	524	315	60.1
1000–1499	1066	164	15.4
1500–2499	1544	107	6.4
2500–3999 (TAGA)	1730	130	7.5
>4000 (TLGA)	154	8	5.2

Table 1. Distribution of deaths by birth weight category for neonates at CMJAH between 2013 and 2015.

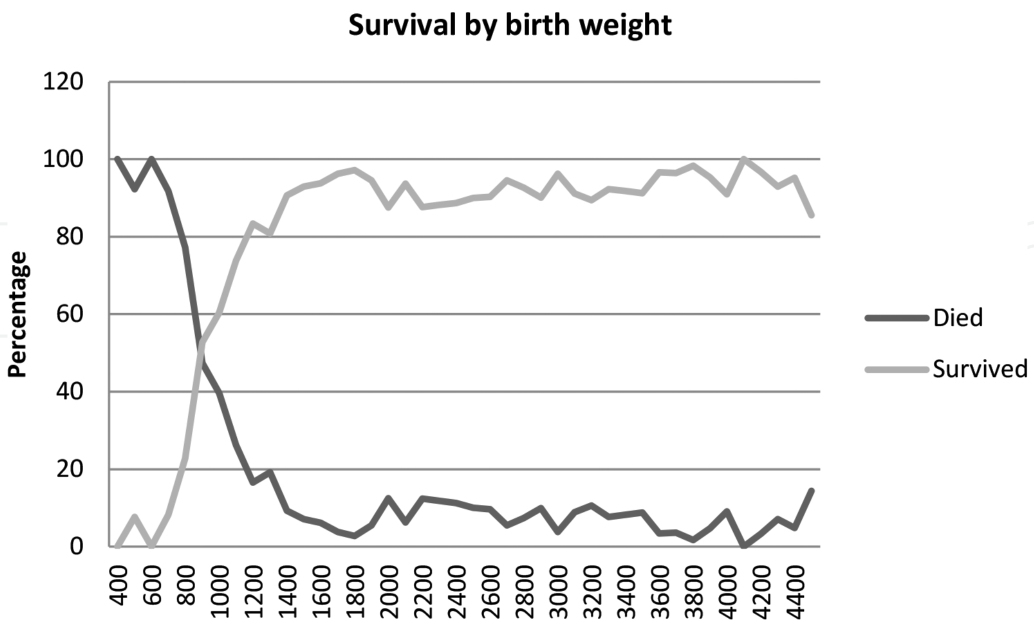

Figure 2. Percentage surviving by birth weight for neonates at CMJAH between 2013 and 2015.

The highly significant association between decreasing birth weight and increasing mortality is shown in **Figure 2** which depicts how the proportion surviving increases as birth weight increases. The percentage survival for a birth weight of 900 g is 52.8.

3.1.1. Demographic and clinical characteristics in VLBW neonates compared to bigger babies

Further results are reported for VLBW neonates compared to bigger babies. Demographic, maternal, and clinical characteristics are shown in **Table 2**. Certain conditions only occur in bigger babies and were thus not reported for VLBW neonates, namely meconium aspiration syndrome (MAS), persistent pulmonary hypertension of the neonate (PPHN), hypoxic ischemic encephalopathy (HIE), and cerebral cooling.

Factor	*Cases*	*%*	*<1500 g*		*>1500 g*		*P-value*
			n	*%*	*n*	*%*	
Birth defect	264	5.4	29	1.9	226	6.8	<0.001
Delivery room death	147	2.9	54	3.5	33	1	<0.001
Birth place							<0.001
-Other unit	718	14.4	162	10.5	552	14.5	
-Born outside health facility	194	3.9	85	5.5	104	3.8	<0.001
-Inborn	4059	81.6	1302	84.1	2707	80.5	
Antenatal care	4017	85.6	1150	77.4	2829	89	<0.001
Antenatal steroids	889	27.8	657	74.5	225	25.5	<0.001
Antenatal magnesium sulfate	102	2.3	65	4.7	37	1.2	<0.001
Chorioamnionitis	127	2.8	47	3.4	79	2.5	0.118
Maternal hypertension	651	14.3	377	27	269	8.7	<0.001
Maternal HIV	1410	29.4	456	31	946	28.9	0.147
Maternal syphilis	79	1.6	29	2.1	48	1.5	0.164
Maternal diabetes	134	2.9	7	0.5	127	4	<0.001
Maternal TB	44	1	11	0.8	33	1.1	0.416
Teenage mother	114	2.3	39	2.7	75	2.4	0.529
Vaginal delivery	2191	44.7	661	43.3	1489	44.9	0.288
Male gender	2752	55	720	46.5	1995	58.7	<0.001
Multiple gestation	586	11.8	272	17.8	301	8.9	<0.001
Delivery room resuscitation	1532	31	643	43.7	850	25	<0.001
Early onset sepsis	173	3.4	62	4.2	111	3.3	0.133
Oxygen on day 28	404	8.1	347	25.6	57	1.7	<0.001

Factor	*Cases*	*%*	*<1500 g*		*>1500 g*		*P-value*
			n	*%*	*n*	*%*	
IVH 3/4	61	1.2			N/A	N/A	
PVL	11	0.2	8	0.7	3	0.1	<0.001
Died within 12 h of admission	70	1.4	39	2.6	31	0.9	<0.001
Pneumothorax	36	0.7	10	0.7	26	0.8	0.444
Pulmonary hemorrhage	32	0.7	27	1.8	5	0.1	<0.001
HIE 2/3	174	3.6	N/A	N/A			
Cerebral cooling	103	38.1	N/A	N/A			
Meconium aspiration syndrome	264	7.8	N/A	N/A			
PPHN	54	1.6	N/A	N/A			
HMD	2004	41.1	1347	89.6	657	19.5	<0.001
NCPAP	1565	32.5	1015	70.1	550	32.5	<0.001
IPPV	692	14.4	299	21	393	11.7	<0.001
NCPAP without IPPV	1228	24.5	795	78.9	433	79.4	0.816
Surfactant therapy	1580	33.1	1038	69.8	542	16.5	<0.001
Steroids for CLD	216	5.7	199	13.8	17	0.7	<0.001
PDA	245	5	152	10.2	93	2.8	<0.001
NEC	156	3.2	107	7.2	49	1.5	<0.001
Other surgery	136	2.9	29	2	107	3.3	0.014
Packed cell transfusion	674	13.4	527	35.9	147	4.4	<0.001
Exchange transfusion	24	1.5	9	1	15	2.2	0.039
Hypoglycemia	525	10.8	185	12.3	340	10	0.02
Hyperglycemia	375	7.7	287	19.1	88	2.6	<0.001
Hypernatraemia	169	3.5	148	9.8	21	0.6	<0.001
Metabolic acidosis	185	3.8	92	6.1	93	2.8	<0.001
Late onset sepsis	608	12.6	421	28.3	187	5.6	<0.001

Table 2. Demographic, maternal and clinical characteristics by birth weight for neonates at CMJAH between 2013 and 2015.

3.2. Risk factors for neonatal death

Neonates who survived were born at a significantly more mature gestational age than those who died (34.8 weeks [SD 4.4] vs. 30.5 weeks [SD 5.5]; $p < 0.001$). Similarly, the birth weight of neonates who survived was significantly greater than those who died (2260 g [SD 932] vs. 1495

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g [SD 940]; $p < 0.001$). Survivors stayed in hospital for a longer period of time than those neonates who died (14.8 days [SD 18.5] vs. 7.1 days [SD 13.3]; $p < 0.001$). Body temperature on admission was significantly higher in neonates who survived compared to those who died (36.3°C [SD8.0] vs. 35.6°C [SD 1.6]).

Conditions significantly associated with death in all the neonates, including those who died in the delivery room, are shown in **Table 3**. Only data for babies who died are reported. The percentages refer to the number of babies who died with and without the various conditions. For example, 38.5% (102) of babies who had a major birth defect died and 12.8% (596) of babies without a major birth defect died. Percentages are reported per the total number of complete cases for each condition—missing data were excluded. All other conditions were not significantly associated with death in the whole group of neonates.

Factor	**Condition present**		**Condition absent**		***P***
	# Died	**%**	**# Died**	**%**	
Birth defect	102	38.5	596	12.8	<0.001
Antenatal care	503	12.5	162	23.0	<0.001
Maternal HIV	209	14.8	433	12.8	0.061
Maternal diabetes	9	6.7	607	13.5	0.023
Vaginal delivery	404	18.4	303	11.2	<0.001
Birth place					
Another unit	100	13.9			
Outside health facility	53	27.3			<0.001
Inborn	569	34.0			
Multiple gestation	101	17.2	612	14.0	0.035
Initial resuscitation	393	25.7	312	9.2	<0.001
MAS	34	`12.9	156	5.0	<0.001
Pneumothorax	12	33.3	559	11.6	<0.001
Pulmonary haemorrhage	24	75.0	558	11.6	<0.001
PPHN	25	46.3	165	5.0	<0.001
Hyaline membrane disease	399	19.9	183	6.4	<0.001
NCPAP	304	19.4	266	8.2	<0.001
IPPV	219	31.6	348	8.5	<0.001
NCPAP without IPPV	205	16.7	98	30.2	<0.001
Surfactant therapy	310	19.6	256	8.0	<0.001

Factor	Condition present		Condition absent		P
	# Died	%	# Died	%	
PVL	4	36.4	424	9.5	0.003
IVH grade 3/4	29	47.5	32	52.5	<0.001
HIE grade 2/3	48	27.9	124	72.1	<0.001
NEC	65	41.7	508	10.9	<0.001
Surgery (not NEC)	38	27.7	524	11.4	<0.001
Blood transfusion	148	22.0	422	10.1	<0.001
Hypoglycemia	78	14.9	504	11.6	0.029
Hyperglycemia	165	44.0	417	9.3	<0.001
Hypernatraemia	64	37.9	518	11.0	<0.001
Metabolic acidosis	101	54.6	481	10.3	<0.001
Late onset sepsis	135	22.0	434	10.3	<0.001

Table 3. Factors associated with death in all neonates who died (*n* = 724), including delivery room deaths.

The results of binary logistic regression, considering whether neonate survived to discharge as the outcome variable, are shown in **Table 4**. The chances of survival decreased with metabolic acidosis, hyperglycemia, mechanical ventilation, major birth defect and the need for resuscitation at birth, while increasing birth weight and gestational age and delivery by Caesarean section were associated with an increased chance of survival.

Condition	Odds ratio	95% CI for OR	
		Lower	Upper
Metabolic acidosis	0.135	0.09	0.204
Hyperglycemia	0.307	0.23	0.409
Mechanical ventilation	0.357	0.278	0.46
Birth weight	1.001	1	1.001
Major birth defect	0.118	0.079	0.175
Gestational age	1.109	1.054	1.167
Caesarean section	1.803	1.444	2.251
Resuscitated at birth	0.395	0.315	0.495
Constant	0.21		

Table 4. Results of binary logistic regression model for factors associated with survival in all neonates at CMJAH between 2013 and 2015.

3.2.1. Binary logistic regression: VLBW neonates

The results of binary logistic regression considering survival to discharge as the outcome variable were performed for VLBW neonates (see **Table 5**). The percentage survival increased with increasing birth weight, delivery by Caesarean section and the use of NCPAP without the need for mechanical ventilation. Maternal HIV, hyperglycemia, resuscitation at birth, pulmonary hemorrhage, NEC, and metabolic acidosis were associated with a reduced chance of survival.

Factor	Odds ratio	95% CI	
		Lower	Upper
Birth weight (g)	1.005	1.004	1.006
Maternal HIV	0.582	0.394	0.861
Caesarean section	1.81	1.242	2.638
Resuscitated at birth	0.589	0.405	0.858
Pulmonary haemorrhage	0.176	0.063	0.493
Necrotising enterocolitis	0.252	0.139	0.459
Hyperglycaemia	0.489	0.325	0.737
Metabolic acidosis	0.098	0.051	0.191
NCPAP without ventilation	2.032	1.314	3.142
Constant	0.022		

Table 5. Binary logistic regression for factors associated with survival to discharge in VLBW neonates at CMJAH between 2013 and 2015.

3.2.2. Binary logistic regression: bigger neonates

The results of binary logistic regression considering survival to discharge as the outcome are shown in **Table 6**. Birth weight was not significantly different between survivors and non-survivors in this weight category. Decreasing gestational age, the need for resuscitation at birth, mechanical ventilation, metabolic acidosis, and hyperglycemia were all associated with a reduced chance of survival.

Factor	Odds ratio	95% CI for OR	
		Lower	Upper
Gestational age (weeks)	0.937	0.881	0.996
Resuscitated at birth	0.375	0.249	0.564
Mechanical ventilation	0.12	0.078	0.184
Metabolic acidosis	0.244	0.122	0.486
Hyperglycaemia	0.16	0.08	0.321
Constant	668.746		

Table 6. Binary logistic regression for factors associated with survival to discharge in bigger neonates at CMJAH between 2013 and 2015.

3.2.3. Delivery room deaths

Neonates who died in the delivery room were less likely to have received antenatal steroids and be delivered to mothers with hypertension or HIV, compared to neonates who died in the neonatal wards. Delivery room deaths were associated with vaginal delivery and were more likely in neonates who had been resuscitated at birth (see **Table 7**). Neonates who died in the delivery room had a lower body temperature on admission than those who died in the neonatal wards (34.6°C [SD 2.8] compared to 35.8°C [SD 1.2]; $p < 0.001$). All other variables including birth weight and gestational age were not different between neonates who died in the delivery room compared to the neonatal wards.

Condition present	Delivery room death	Percentage	Neonatal ward death	Percentage	*P*-value
Antenatal steroids	15	9.4	144	32.3	0.001
Maternal hypertension	12	12.2	86	17.3	0.032
Maternal HIV	25	21.6	184	35.2	0.004
Caesarean section	51	35.4	252	44.8	0.042
Resuscitated at birth	95	64.6	297	53.2	0.013

Table 7. Maternal and delivery room factors compared between babies who died in the delivery room and those who died in the neonatal wards.

4. Discussion

The ongoing audit of neonatal mortality and neonatal care to determine risk factors for poor outcome is essential so that correct interventions can be implemented. The MDG 2015 report states that better readily available data is urgently needed to guide health policies [1]. There is a slogan in the report that says “together we can measure what we treasure”. The so-called “Plan Do Study Act [PDS] cycle is a tool for quality improvement projects [10]. Ongoing clinical audit is fundamental to quality improvement projects, both for planning the intervention and then measuring the benefit of the intervention [11, 12]. It is also essential to have appropriate local data available; different NICUs and neonatal populations have different problems and need tailored solutions. For example, maternal HIV is an important issue in the current study, but would not apply in a European setting.

The best example of clinical audit and quality improvement in neonatal care is the Vermont Oxford Network [VON] (www.vtoxford.org). The VON is a multinational multicenter collaboration of neonatal units established in 1989 with the aim of improving quality and effectiveness of neonatal care by research, education and quality improvement projects [13]. There are currently more than 1000 neonatal units from around the world that participate in the VON. Collaborative multi-disciplinary quality improvement projects [NIC/Q] are conducted annually [14].

The present study was an audit of neonatal survival and risk factors for poor outcome in Johannesburg, South Africa. The overall neonatal survival rate in the present study was 85.6%.

Birth weight greatly influenced survival with 69.1% of VLBW surviving compared to 92.1% of neonates above 1500 g birth weight. The VLBW survival in our unit was significantly less than that reported in the VON [www.vtoxford.org] for the same period (69.1% vs. 85.6%). Neonatal mortality rates among different neonatal units are highly variable, but the rates reported in the present study are within the reported range for developing nations [3]. The current neonatal survival rates are better than those reported from NICUs in The Gambia [4] and Ethiopia [15], but worse than those reported from a NICU in Thailand [16]. It must be noted that different mortality rates will be reported depending on which neonates are included in the audit—the present study included neonates from 400 g birth weight and those who died within the delivery room—omission of these would improve the results.

The most important causes of neonatal death in the present study were complications of prematurity, perinatal asphyxia, infection, and birth defects. These findings are similar to other studies evaluating risk factors for neonatal mortality [1, 17], although the contribution of prematurity to neonatal death is considerably higher than that reported in United Nations Millennium Development Goal Report 2015 [1] (42.3% vs. 35%). Birth weight is closely linked to gestational age in LBW neonates; the higher mortality with decreasing birth weight in the present study corresponds to increasingly premature neonates. It is interesting to note that in bigger babies, gestational age, rather than birth weight, was associated with survival. Almost 15% of deaths in the present study were due to congenital abnormalities; this reflects the fact that the unit was a referral centre for pediatric surgery; so many neonates with major congenital abnormalities were referred in for surgery.

The present results are also similar to a report from a private healthcare group in South Africa, who found that birth weight, Apgar score, and mode of delivery were all associated with neonatal mortality [18]. This is interesting, as the majority of patients in the private health care group were of White and Indian ethnicity, whereas those in the current report were almost exclusively Black African.

Most of the neonatal deaths in the current study occurred in VLBW neonates; therefore resources need to be focused on this group of neonates in order to reduce childhood mortality. Decreasing birth weight, maternal HIV, the need for resuscitation at birth, pulmonary hemorrhage, NEC, hyperglycemia, and metabolic acidosis were all associated with a decreased chance of survival in VLBW neonates, while delivery by Caesarean section and the use of NCPAP without the need for mechanical ventilation significantly increased survival. These findings are similar to reports from the same unit [5, 6]. Interventions need to be devised to address these specific risk factors, such as ensuring prevention of mother to child transmission of HIV, providing proper prompt neonatal resuscitation, maintaining normoglycemia, and promoting breastfeeding. All preterm neonates, irrespective of birth weight, should be provided with NCPAP. The use of surfactant and mechanical ventilation may not be available in all NICUs in LMICS due to resource limitations. If necessary, surfactant and mechanical ventilation can be rationed using prognostic criteria. The association of better survival with Caesarean section is a more difficult one – it is possible that neonates delivered by Caesarean section are the "better babies." These mothers may have attended antenatal care, been admitted earlier in labor, and received antenatal steroids. It is therefore possible that Caesarean section is a confounding variable. It is certainly not feasible to suggest that all preterm neonates in LMICS be delivered by Caesarean section. Other factors such as antenatal care, antenatal steroid use, and neonatal infection were not significantly predictive of survival in the present study. This does not mean, however, that regular antenatal care attendance, the use of antenatal steroids, and infection control should be omitted from interventions to improve VLBW survival.

The factors associated with poor survival in bigger neonates included decreasing gestational age, the need for resuscitation at birth, mechanical ventilation, metabolic acidosis, and hyperglycemia. This emphasizes the need for all birth attendants to be skilled in neonatal resuscitation. It is possible that mechanical ventilation will not be available in many NICUs in LIMICs, but bigger preterm infants can be successfully managed with surfactant therapy and NCPAP [9].

A recent report from Burundi showed that the neonatal survival rates were significantly improved in a low resourced district hospital, without specialist care [19]. This was achieved by integrating neonatal and obstetric services, with an emphasis on prompt referral and transfer of mothers in preterm labor, the ongoing on-site training of staff with clear protocols for case management, provision of essential equipment, and providing complementary kangaroo mother care and NICU facilities.

In conclusion, ongoing clinical audit is integral to the process of quality improvement, to develop appropriate health care policies and to monitor the impact of these policies. Focus on neonatal care and especially that of VLBW neonates is essential if we are to achieve the SDG goal of reducing neonatal mortality to 12 per 1000 births.

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