Neonatal Mortality in the Cape Town Metro West Geographical Service Area 2014-2017

by

CANDICE NELSON AFONSO
NLSCAN001

SUBMITTED TO THE UNIVERSITY OF CAPE TOWN
In partial fulfilment of the requirements for the degree

MPhil Maternal and Child Health

Department of Paediatrics and Child Health

Faculty of Health Sciences

UNIVERSITY OF CAPE TOWN

Date of submission: 10 February 2020
Supervisor [s]: Prof Michael Hendricks

Dr Natasha Rhoda

Dr Adelaide Masu

Contents

Declaration 1

Acknowledgements 2

Abbreviations: 3

Abstract 4

Background 4

Objectives 4

Methods 4

Results 4

Conclusions 5

Chapter 1: Introduction: Background and Literature Review 6

1.1 Millennium Development Goals 6

1.2 Every Newborn Action Plan (ENAP) 8

Antenatal Care 9

1.3 Sustainable Development Goals 9

1.4 Sub-Saharan context 9

1.5 The South African Context 10

1.6 Perinatal data collection 11

1.6.1. National Databases 11

1.6.2 Rapid Mortality Surveillance System 12

1.6.3 Household Survey 12

1.6.4. Facility based Audit Systems 13

1.6.5 The Child Death Review 15

1.7 Avoidable or Modifiable Factors 19

1.8 Geographical Service Areas (GSAs) as health districts: 20

1.9 Problem Statement: 20

1.10 Aim 20

1.11 Study Objectives 21
Chapter 2: Methodology 22
2.1 Definitions: 22
2.2 Study setting 22
2.3 Study Design 24
2.4 Study Duration 24
2.5 Study population 24
2.6 Research Procedure 25
2.6.1 Data Collection 25
2.6.2 Data Analysis 26
2.7 Ethics, reliability, validity, generalizability: 26
Ethics 26
Chapter 3: Results 27
3.1 Neonatal Mortality; numbers and rates 27
3.1.1 Total deliveries and total livebirths 27
3.1.2 Neonatal Deaths 27
3.1.3 Neonatal Mortality 29
3.1.4 Perinatal features of the neonatal deaths 30
3.2 Causes of Death 36
3.2.1 Perinatal Problem Identification Programme 36
3.2.2 Child Healthcare Problem Identification Programme 38
3.2.3 Child Death Review/ Forensic Pathology Service 39
3.2.4 Aggregated cause-specific mortality rates 41
3.3 Preventable neonatal mortality 44
3.3.1 Avoidable Factors Perinatal Problem Identification Programme 44
3.3.2 Avoidable Factors Child PIP 45
3.3.3 Avoidable Factors FPS/CDR 46
Chapter 4: Discussion 48

4.1 Introduction 48
4.2 Neonatal Mortality 48
4.3 Causes of neonatal deaths: 51
4.4 Preventable deaths 54
4.4.1 Patient related factors 55
4.4.2 Healthcare personnel related 57
4.5 Limitations 58
4.6 Recommendations 60
4.7 Conclusions 61
List of References 63
Appendices 72
Appendix 1: Table of the variables used in the study 72
Appendix 2: Obstetric cause of perinatal death (PPIP version 3) 72
Appendix 3: Final cause of neonatal death (PPIP version 3) 73
Appendix 4: Final cause of child death (Child PIP version 3.1) 74
Appendix 5: Avoidable factors (PPIP version 3) 75

List of Figures:

Figure 1: A map of the Cape Town Metropole Health Districts…….23
Figure 2: Number of neonatal deaths from each audit system 2014-2017…….29
Figure 3: NMR for each dataset and total from 2014-2017……30
Figure 4: PPIP: Causes of death all neonates >500g……...36
Figure 5: PPIP: Causes of death all neonates >1000g……37
Figure 6: Child PIP: Causes of neonatal death 2014-2017…….39
Figure 7: Medicolegal description of CDR/FPS neonatal deaths 2014-2017……39
Figure 8: Main causes of neonatal deaths across all three datasets 2014-2017……..41
Figure 9: Contribution of number of deaths per cause of death from each audit system……42
Figure 10: Main causes of neonatal deaths across all three datasets all neonates >1000g 2014-2017...42
Figure 11: Main causes of neonatal death for all neonates >500g per year 2014-2017…….43
Figure 12: Main causes of early neonatal deaths across all three datasets for all neonates >500g……43
Figure 13: Main causes of late neonatal deaths across all three datasets for all neonates >500g……44
Figure 14: Avoidable factors PPIP 2014-2017…….…..45
Figure 15: Avoidable factors Child PIP 2014-2017……...46

List of Tables:

Table 1: Total deliveries per weight category 2014-2017…….27
Table 2: Total livebirths per weight category 2014-2017…….27
Table 3: Number of neonatal deaths in each audit group 2014-2017……28
Table 4: NMR for each dataset and total of the three 2014-2017 (per 1000 live-births)..……29
Table 5: NMR: >500g, >1000g and per weight category 2014-2017……30
Table 6: Perinatal factors: Maternal……33
Table 7: Perinatal factors: Neonatal……35
Table 8: Description of unnatural causes of death in CDR/FPS data 2014-2017……...40
Table 9: Top avoidable factors coded PPIP 2014-2017…….45
Table 10: Top modifiable factors coded Child PIP 2014-2017……...46
Table 11: Top avoidable factors coded CDR/FPS 2014-2017……47

Declaration

I, *Candice Nelson Afonso*, hereby declare that the work on which this dissertation/thesis is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

I empower the university to reproduce for the purpose of research either the whole or any portion of the contents in any manner whatsoever.

Signature

Signed by candidate

Date: 8 February 2020

Acknowledgements

My utmost thanks to my supervisors for their patience, care and support

My thanks to Leigh Anne van Balla and Karen Stone who assisted me with folders at Mowbray maternity hospital and the Midwife Obstetric Units.

To Cindy Stephen for all your help with Child PIP.

And to Gabeba Abass, we miss you every day.

And to my family, my children that have grown up asking about my thesis and being ever so proud and supportive of mommy. And to my husband and often-time sounding board- it is done now!

Abbreviations:

ARR	Annual reduction rate
CDR	Child Death Review
Child PIP	Child Healthcare Problem Identification Programme
DHA	Department of Home affairs
DHIS	District Health Information System
ELBW	Extremely Low Birthweight
ENAP	Every Newborn Action Plan
ENMR	Early Neonatal Mortality Rate
FPS	Forensic Pathology Services
GSA	Geographical Service Area
KMC	Kangaroo Mother Care
LBW(R)	Low birthweight (rate)
LNMR	Late Neonatal Mortality Rate
MDG	Millennium Development Goal
MOU	Midwife Obstetric Unit
MRC	Medical Research Council
NaPeMMCo	National Perinatal and Neonatal Morbidity and Mortality Committee
NMR	Neonatal Mortality Rate
PPIP	Perinatal Problem Identification Programme
SDG	Sustainable development Goal
SUDI	Sudden unexpected death of an infant
U5M(R)	Under five mortality (rate)
UN	United Nations
VLBW	Very Low Birthweight
VR	Vital registration (data)
WHO	World Health Organisation

Abstract

Background

Each neonatal death counts, as recognised by the Every Newborn Action Plan (ENAP). This is an important aspect in attaining the third Sustainable Development Goal by 2030. Accurate neonatal mortality data as well as an understanding of the causality and context is essential to plan interventions to reduce neonatal deaths and attain the third Sustainable Development Goals (SDG) of a neonatal mortality rate of less than 12 per 1000 livebirths by 2035.

Objectives

The objectives of this study were: (i) to determine neonatal mortality occurring in and out of health facilities in the Metro West GSA using the three audit programmes; Perinatal Problem Identification Programme (PPIP), Child Healthcare Problem Identification Programme (Child PIP) and Forensic Pathology Services (ii) to ascertain the cause of death specific neonatal mortality (iii) to describe the avoidable factors in each death as coded by the three audit programmes (iv) to make recommendations for the alignment of existing audit databases to obtain accurate neonatal statistics for the Metro West GSA.

Methods

This was a retrospective descriptive study of neonatal deaths undertaken in the public healthcare setting in the Cape Town Metro West GSA from January 2014 till December 2017. Existing data from PPIP, Child PIP and the CDR/FPS was used. Neonatal deaths were defined as in the first 28 days of life where there had been signs of life at delivery and a birthweight greater than 500g. Neonatal deaths were excluded where birth had occurred outside of the GSA or in the private health care setting. The audit data with regards to cause of death and avoidable or modifiable factors was obtained for each death.

Results

From a total of 134843 live deliveries, 1243 neonatal deaths were identified: 976(78%) from PPIP, 58(5%) from Child PIP and 209 (17%) from CDR/FPS. Sixteen per cent of the deaths occurred outside of healthcare facilities. The neonatal mortality rate (NMR) for PPIP was 7.2, Child PIP 0.43 and CDR 1,6 per 1000 livebirths. When the audit systems were combined, the annual NMR over the study period varied from 8.05 to 10.1 with a mean of 9.2 per 1000 livebirths over the entire period. Seventy-eight per cent of the deaths occurred in the early neonatal period with a mean early neonatal mortality rate of 7.2 per 1000 livebirths. The mean late NMR was 2 per 1000 livebirths. Where all neonatal deaths were considered for those more than 500g, the main cause of death was immaturity related, then infection related followed by congenital disorders and then hypoxia related. Seventy-four per cent of deaths occurred in those less than 2500g at birth and 41% were less than 1000g and

defined as extremely low birthweight. In the group of neonates greater than 1000g, the main cause of death was infection related deaths, closely followed by congenital disorders and then hypoxia, followed by immaturity. Most of infection related deaths were collected by the CDR and Child PIP. A third of Child PIP and PPIP deaths and half of the CDR deaths were coded as avoidable. The prevalence of deaths due to abandonment either by passive or active neonaticide contributed towards the higher proportion of preventable deaths in the CDR group.

Conclusions

The burden of deaths due to immaturity is high and may be attributed to the finding that 41% of neonatal deaths were in the ELBW group. Current viability criteria that aim at optimum use of resources may improve survival amongst this group. Infection related deaths were shown by this study to have a greater burden than recorded from PPIP data; most of these deaths were derived from Child PIP and CDR data. Also, where 10% of neonatal deaths were sudden unexpected deaths (SUDIs), a better understanding and definition of this group is urgently required as many of these deaths were subsequently found to be secondary to lower respiratory infections. It is further relevant that where 20% of CDR deaths or 3% of all the study deaths were due to active and passive neonaticide, this entity should be monitored and investigated.

The study showed that the GSA has achieved the SDG for NMR of less than 12 per 1000 livebirth. However, a mean NMR of 9.2 per 1000 livebirths is not comparable to other upper middle-income countries. As 38% of the deaths were coded as avoidable, appropriate programmes to address these factors could reduce the NMR to 5.7 per 1000 livebirths.

A strong recommendation from this study would be to use all three audit systems to calculate the NMR, understand the causes of neonatal deaths and plan programmes to improve neonatal survival in this GSA.

Chapter 1: Introduction: Background and Literature Review

This literature review outlines the major international goals namely, the Millennium Development Goals (MDG) and Sustainable Development Goals (SDG). It describes those programmes that were commenced in Sub-Saharan Africa and in South Africa. The implications for perinatal practice in the Metro West Geographical Service Area (GSA) of Cape Town, South Africa, is explored within the context of accurate neonatal mortality estimations and an understanding of the reasons why neonates are dying in this GSA. The emphasis is on identifying preventable mortality and improving survival.

1.1 Millennium Development Goals

The MDGs were a global effort initiated by the United Nations in 2000 which identified eight global health priorities. MDG 4 highlighted the importance of child health and called for a two thirds reduction of under-five mortality (U5M) by 2015. This resulted in the doubling of donor funding of programmes aimed at improved immunisation coverage, prevention and treatment of HIV, tuberculosis and malaria and, importantly, had marked effects on childhood survival (Lawn *et al.*,2014:189).

By the end of the MDG era in 2015, there were 4 million less deaths globally in children under the age of five than there had been in 2000 (Liu *et al.*,2016a: 3031, 3032). However, in comparison to other causes of U5M, there had been a slower decline in neonatal deaths. It was estimated that if the neonatal mortality rate (NMR) had declined at the same velocity as other causes of U5M, then the goal of a two thirds reduction in U5M would have been attained before the target date of 2015 (Liu *et al.*,2016a: 3031, 3032).

The Every Newborn Study Group produced a *Lancet Series* (2014) to evaluate the progress of the MDGs with the aim of providing an evidence-based approach to diminish the burden of preventable neonatal mortality (Bhutta *et al.*,2014:347). The series highlighted at least four important learning points:

1.An equity gap exists between countries:

The reduction in neonatal mortality showed great disparity between regions. To achieve MDG 4, countries had to achieve an annual reduction rate (ARR) of at least 4.3% in U5M. Large rapid reductions were seen in better resourced countries and very small slow reductions in poorer resourced regions such as sub-Saharan Africa (Liu *et al.*,2016a: 3032). It was calculated that if the rate of decline of neonatal mortality in 2013 was maintained in Africa, it would take a hundred years for a child born in Africa to have the same chance of survival as a child born in Europe or in North America (Lawn *et al.*,2014:191).

2. There are specific causes of neonatal deaths:

To design specific programmes it became important to understand why neonates were dying. Global figures showed that the main causes of death were complications related to immaturity, intra partum hypoxia and infections. Deaths due to preterm complications were a major component of all countries irrespective of their NMR. In countries where the NMR decreased, congenital malformations started to take a larger proportion of the causes of death. Whereas in countries where the NMR remained high, deaths due to infection and intrapartum hypoxia still dominated as causes of death (Lawn *et al.*,2014:196). So, tracking the reduction rate in cause-specific mortality can potentially predict into which mortality pattern a region fits.

3. The timing of neonatal deaths is important:

Globally, one million babies (thirty per cent) die within the first twenty-four hours (Lawn *et al.*,2014:195). The first week of life remains a period of high risk with seventy-five per cent of all neonatal deaths usually occurring during this period (Lawn *et al.*,2014:196). These early neonatal deaths are due to complications of preterm birth and intrapartum hypoxia. After the first week of life, late neonatal deaths, are related more to infections and particularly sepsis (Lawn *et al.*,2014:6). The evidence does not comment whether this sepsis is related to hospital acquired infections or to congenital sepsis.

4. Simple interventions have a large impact on survival:

Evidence was reviewed of specific interventions that could be applied along the continuum of care, from the antenatal period through labour to the postnatal period, to improve neonatal survival by looking at the main causes of neonatal deaths (Bhutta *et al.,* 2014:347).

Antenatally interventions have been identified to have a significant positive effect on neonatal mortality include: antibiotics for preterm premature rupture of membranes (relative risk 0.88 95% CI 0.8-0.97), steroids for preterm labour (relative risk 0.47, 95% CI 0.35-0.64), basic emergency obstetric care (relative risk 0.60, 95% CI 0.48-0.60) and, skilled birth care (relative risk 0.75, 95% CI 0.70-0.85) (Bhutta *et al.*, 2014:354).

Every pregnant woman and neonate should have access to skilled birth attendants who are able to perform specific interventions at birth. Neonatal resuscitation for those neonates that are not breathing at birth is essential (relative risk 0.7, 95% confidence interval 0.59-0.84). Other postnatal interventions include immediate drying in a warm environment especially for preterm infants (relative risk 0.8, 95% CI 0.55-0.92), hygienic care and, the administration of vitamin K with immediate breastfeeding after birth. Ongoing support should include cord care such as the use of chlorhexidine to clean the umbilical stump and support of the mother to breastfeed (Bhutta *et al.* ,2014:354).

Improved care of the preterm neonate looked at use of antenatal corticosteroids to improve lung maturity, delayed cord clamping, prevention of hypothermia with the use of plastic bags and the use

of continuous positive airways pressure ventilation (Bhutta *et al.*, 2014:348). The use of intra tracheal surfactant is significant when used preventatively in preterm infants (relative risk 0.60, 95% CI 0.47-0.77) and when used in the treatment of babies with respiratory distress syndrome (relative risk 0.68, 95% CI 0.57-0.82) (Bhutta *et al.*, 2014:348).

Kangaroo Mother Care (KMC) is highlighted as an intervention with very high impact on neonatal survival, particularly in preterm infants (relative risk 0.60, 95% CI 0.39-0.930). The practise of early continuous skin to skin contact of the mother with her preterm infant decreases neonatal mortality by 51%, decreases the risk of hospital acquired infections and sepsis by 58 % and increases exclusive breastfeeding rates in the first four months of life by 28% (Bhutta *et al.*, 2014:355).

1.2 Every Newborn Action Plan (ENAP)

The data and evidence collated in *The Lancet* Every Newborn Series witnessed the collaboration of over 300 international stakeholders from government, healthcare professionals and non-governmental organisations under the guidance of WHO and UNICEF to formulate the Every Newborn Action Plan which was launched in Johannesburg, South Africa. ENAP acknowledged that improving perinatal survival needed to remain a goal in the post-MDG era (WHO, 2014:1)

This plan aimed to focus on eighty per cent of neonatal deaths that were due to preventable and treatable causes such as complications due to immaturity, intrapartum hypoxia and neonatal infection (WHO, 2014: 6). The emphasis falls very strongly on the attendance of a skilled midwife or trained health worker to assist with care during labour, delivery and in the early neonatal period for every mother and neonate. The plan focuses on improved quality of care for every woman and her neonate using simple and effective interventions that are evidence based. These measures include; resuscitation of the neonate during the golden minute after delivery, appropriate antibiotic care for infections, kangaroo mother care and support of breastfeeding (WHO, 2014: 6).

It is estimated that these cost-effective interventions can save the lives of three million neonates and mothers (WHO, 2014:6). To achieve this, an ARR of 4.3% of the NMR is required (Lawn *et al.*,2016:172). The final aim is to achieve an NMR of less than twelve deaths per 1000 live births in every country by 2035 (Mason *et al.*,2014:2).

As we move towards 2035, this plan recognises the fact that each country needs to adapt these action plans to meet their specific context. This could extend to the identification of the skilled birth attendant and the training that is required to achieve the implementation of the interventions that have been identified. But essentially there should be uniformity along the lines of a national plan to which stakeholders are ultimately accountable (Mason *et al.*,2014:3).

Antenatal Care

Antenatal care is an essential part of ensuring a healthy mother, pregnancy and a healthy neonate. The WHO model of focused antenatal care described the necessity of at least four antenatal visits. These visits were designed and structured to continue to assess the clinical risk of the mother and fetus to prevent any potential complications. However, a review of antenatal care showed that only 52% of women worldwide attended four antenatal visits (Downe *et al.*,2015:529).

A qualitative review of antenatal care revealed that this precise method of antenatal care did not attend to the psychosocial factors around pregnancy. The analysis showed that by engaging with women on a social, cultural, emotional and psychological level, healthcare workers would encourage pregnant women to engage more with the antenatal healthcare services. Mothers were calling for a positive pregnancy experience that would allow them to transition to motherhood more effectively (Downe *et al*.,2015:534).

1.3 Sustainable Development Goals

The Sustainable Development Goals (SDGs) commit to continue global strategies started by the MDGs by committing to attain 17 goals and 169 targets by 2030 (United Nations, 2015a). SDG 3 is the only health related goal which aims to improve health and well-being at all ages and focuses on the ability for individuals to reach their full potential (Barosa *et al*.,2016:136). Other goals acknowledge the importance of social, economic and environmental factors.

The SDG target for child health is to achieve an U5MR of less than 25 per 1000 live births and an NMR of less than 12 per 1000 live births (United Nations,2015a:3). As a legacy of the MDGs, this will not be achievable without actively addressing the lag in decrease of the NMR, especially as these are mostly preventable or curable (Norheim *et al.*,2015:241). An ARR in neonatal mortality of 4.3 % as outlined in ENAP would need to be achieved.

The Global Strategy for Women's, Children's and Adolescent health outlined by the United Nations is closely aligned with the SDGs. The three tenants of this strategy are to "survive, thrive and transform". The implication is that this strategy aims not only to diminish preventable mortality, but also to attain a better quality of survival by the year 2030 (United Nations, 2015b:6). In the neonatal context this too can be affected by complications related to prematurity, intrapartum hypoxia and neonatal infections with interventions and packages aimed at the antenatal, intrapartum and postnatal period.

1.4 Sub-Saharan context

A quarter of all liveborn neonates are delivered in sub-Saharan Africa. This accounts for a large and growing proportion of the world's neonates. Further estimates show, with current trends, an increase by a third of this number is expected by 2030 (UN Inter-agency group for Child Mortality estimation 2017:8).

This region of the world faces specific challenges such as the HIV/AIDS epidemic, conflict crises, poverty and inequity (Kinney *et al.*,2010:4). Rural areas suffer from a scarcity of resources and access to healthcare services, whilst the rapid onset of urbanisation has resulted in overcrowding, unsanitary living conditions and worsening poverty (Kinney *et al.*,2010:4). Gender inequality in the region has also resulted in specific challenges as women are not empowered to exercise good health seeking behaviours and access healthcare services (Kinney *et al.*,2010:4).

At the start of the MDG era, half of global U5M occurred in sub Saharan Africa. Progress towards achieving MDG 4 was slow, as improvement in neonatal mortality was much slower. In fact, difference between ARR of mortality between neonates and under-five year old children was most marked in this region of the world (Liu *et al.*,2016a:3032). The United Nations Inter-Agency Group for Child Mortality estimation (2017) highlighted that most countries that need to accelerate programmes to improve childhood survival by 2030 and achieve the SDGs, are in sub Saharan Africa. Furthermore, this region is also burdened by the increasing number of births (UN Inter-Agency group for Child Mortality estimation 2017:8).

Nearly ninety per cent of neonatal deaths in this region are due to prematurity (28%), neonatal infections (28%) and intrapartum hypoxia (28%) (Kinney *et al.*2010:4). These causes would respond well to the simple measures promoted by ENAP such as improved care around the time of birth, thermal care, hygiene, breastfeeding and timeous treatment of neonatal infections (UN Inter-agency group for Child Mortality estimation 2017:11).

1.5 The South African Context

South Africa made very slow progress in attaining MDG 4 from 1990 till 2012 and did not achieve MDG 4 by 2015. It was one of few countries that initially showed a rise in the U5MR which peaked in 2004/2005 and thereafter began to decline. The increase in mortality was attributed to the HIV epidemic and affected all age groups (Mayosi *et al*., 2012:9*)*. An improved ARR of 10.3% from 2006 till 2011 resulted in a decrease of the U5MR from 68.9 to 42.2 per thousand livebirths (Bradshaw, Dorrington & Laubscher, 2011:13,14). In comparison to this, the NMR remained constant with an ARR estimated between 2.3 and 3.4 per cent (Kerber *et al.*,2013: 2643).

Three ministerial committees were launched in 2008 to review deaths and give oversight over the implementation of programmes to achieve the MDGs. The National Perinatal and Neonatal Morbidity and Mortality Committee (NaPeMMCo) was one of these and tasked to develop recommendations on strategies to reduce perinatal and neonatal deaths (Statistics South Africa, 2015:6).

In line with recommendations from the ministerial committees, government launched programmes targeting perinatal health such as the Strategic Plan for Maternal, Newborn Child and Women's Health and Nutrition (Rhoda *et al.*,2014:160). The main causes of death in the neonatal period were identified as complications due to prematurity, intrapartum hypoxia and neonatal infection. This is in

keeping with the profile of sub-Saharan Africa. Strategies were built around better access to care and strengthening Primary Health Care Services (Rhoda *et al.*,2014:160).

In keeping with the recommendation by the WHO, the antenatal care services were also realigned. The Basic Antenatal Care package (BANC) went from a recommendation of four to eight antenatal care visits. The aim was for antenatal care to be established as soon as possible and to have more regular visits near the end of the pregnancy. This contact plan was based on findings that suggested higher maternal and perinatal mortality in cases where there was little contact at this time. But importantly also to ensure the presence of a delivery plan at a suitable level of care attended by a skilled birthing attendant (WHO, 2016).

1.6 Perinatal data collection

Accurate and current perinatal mortality data is required to properly gauge a response to programmes to improve mortality (Bradshaw *et al.*, 2008:1294). During the MDG era it became apparent that there were various sources for mortality data. These do not always deliver the same mortality rates, and each offers some advantage to the process. This section will describe the national databases, household surveys and facility-based audit systems used in South Africa.

1.6.1. National Databases

There are two primary national databases in South Africa that collect data regarding perinatal deaths, the District Health Information System (DHIS) and Department of Home Affairs (DHA). The DHIS collects the number of stillbirths and neonatal deaths that occur in public healthcare institutions. This data is sent from each institution to district, then provincial and then finally to national level. DHIS data with regards to total recorded births in public health facilities and information about health service coverage such as antenatal visits, is accurate and can be presented at sub district and national levels (Bamford *et al.*, 2018:27). However, perinatal mortality indicators are not always consistent. Late neonatal deaths are often incomplete as the deaths occur outside of the period of counting due to calendar month differences, or the deaths occur at child health facilities and not the birth units (National Perinatal Morbidity and Mortality Committee [NaPeMMCo],2011:4). DHIS data also remains an underestimate as it does not include births or deaths that occur in the private sector or at home (NaPeMMCo,2011:3).

The Department of Home Affairs (DHA) records vital registration (VR) data such as births and all reported deaths which are entered onto the National Population Register (NPR). The accuracy of this data is affected by non-registration of births as well as of deaths. A death cannot be registered on the NPR if the birth has not been registered yet. Delayed birth registration has led to inaccuracy of the NPR for deaths occurring in those less than one year of age, and particularly in the neonatal period. Deaths may also not be registered if the notification form does not reach the Department of Home Affairs (Bamford *et al.*, 2018:27). VR coverage in South Africa in rural areas has also been

historically poor. Strategies to improve this have resulted in an increase in the numbers of births and deaths registered. However, there is still a long lag time before these results are available as the reports are generally published two years later (Bamford *et al.*, 2018:27).

Apart from collecting the number of births and deaths, VR also includes the opinion of a medical practitioner on the cause of death. Statistics South Africa (Stats SA) codes the underlying cause which precipitated the chain of events that led to the death as the cause of death (Bamford *et al.* 2018:29). In 2010, this form was modified to include a section which asked for more detailed information in the instance of a perinatal death. This coding system looks at maternal and neonatal factors in determining a cause of death. This is potentially a great step forward in understanding the context of a perinatal death. Despite this mechanism, by the end of 2015 just less than fifteen per cent of the cause-of-death collected for U5M remained ill-defined (Bamford *et al.*, 2018:27).

1.6.2 Rapid Mortality Surveillance System

The DHA vital registration data is forwarded to Statistics South Africa (Stats SA) for the compilation of the Rapid Mortality Surveillance (RMS) Report by the Medical Research Council for all age groups (Statistics South Africa. 2015: 8). The purpose of the RMS report is to release data from vital registration more frequently and it is released annually (Bamford *et al.* 2018:26). Vital registration data has not been used for the neonatal mortality rate in the most recent surveillance report due to the under reporting of births and deaths. Estimates of births and deaths were calculated based on the total delivery and mortality data received from the DHIS as this has been shown to be more statistically accurate (Bamford *et al.*, 2018:26). This report only advises on mortality rates at the national level and not at district level. The RMS (2016) reports an NMR of 12 per 1000 live births for the period from 2013 till 2016, which is the same as the baseline measure of 2012 (Dorrington *et al.*,2018:14).

1.6.3 Household Survey

The South African Demographic and Health Survey (SADHS) in 2016 was conducted by Statistics South Africa (Stats SA) and the South African Medical Research Council. This was a household survey where a representative sample of households were recruited, questionnaires completed, and as part of the study, detailed histories were taken from women with regards to their pregnancy and the delivery of the baby (National Department of Health [NDoH],2017:3).

This report indicated a neonatal mortality rate of 21 per 1000 live births which is markedly higher than the other sources of data (NDoH,2017:18). This survey could potentially report more deaths as it includes deaths that have occurred outside of healthcare facilities or were not registered by the DHA (Bamford *et al.*, 2018:26). There are two other factors that might explain a higher neonatal mortality rate: stillbirths misclassified as neonatal deaths and the classification of a neonatal death occurring in the first thirty-one days of life as opposed to the first twenty-eight days of life (Rhoda *et al.*,2018:5)

The current concern is that stillbirths are often misclassified as neonatal deaths when data is obtained via surveys. Liu *et al* (2016b) investigated this phenomenon in Malawi and the study suggests that one fifth of neonatal deaths were misclassified and more likely to have been stillbirths (Liu *et al.*,2016b:4/11). Part of this study looked at redesigning the questionnaire to look at more discerning markers such as fetal movement immediately before delivery (Liu *et al.*,2016b:4/11). If redesigned, household surveys could contribute greatly to improved counting of stillbirths and neonatal deaths especially in low to middle income countries. However, the SADHS is costly to undertake and is ideally performed every five years (Bamford *et al.*,2018:27).

1.6.4. Facility based Audit Systems

1.6.4.1 The Perinatal Problem Identification Programme

To assist with the process of collecting data about stillbirths and neonatal deaths as well as an understanding of the cause of death and health systems related issues, the Perinatal Problem Identification Programme (PPIP) was developed in 1999 by the Medical Research Council (MRC) It was adopted as a voluntary system for perinatal audit and investigation of deaths occurring in public health facilities but has now been identified as a mandatory process by the National Department of Health (Rhoda *et al.*,2014: 161).

The PPIP data is collated every two years into the *Saving Babies* report. The most recently published tenth report of *Saving Babies* (2017) for the period from 2014 to 2016 in South Africa reported an early neonatal mortality rate (ENMR) of 9.4 per 1000 live births for all babies that had a birthweight of 500g or more. The two major causes of death for all neonates were immaturity related causes (48%) and intrapartum hypoxia (24%). When only including neonates that have a birthweight of 1000g or more, the ENMR is 6.3 per 1000 live births. For this group, the two major causes are hypoxia related causes (35%) and immaturity related causes (29%) (NaPeMMCo,2017:24).

Saving Babies reports historically on the early neonatal mortality rate as opposed to the neonatal mortality rate. Since PPIP is based mainly in perinatal units, it is most efficient at collecting data with regards to stillbirths and early neonatal deaths. Seventy-three per cent of neonatal deaths occur in the early neonatal period (Lawn *et al*.,2016:176). However, many of the international programmes, including the SDGS, base their targets on the neonatal mortality rates. There would be great benefit in being able to report on a neonatal mortality rate to measure where a health district stands within these targets.

As a form of quality control, NaPeMMCo compares the data collected by DHIS and PPIP. Nationally, DHIS data frequently reports more deliveries. This may be because there is no 500g weight cut-off and so more deliveries are counted. When the mortality rates are reported, PPIP reports more deaths than DHIS in certain provinces, including the Western Cape (NaPeMMCo,2017:33).

In the Cape Town Metro West GSA, the same healthcare workers collect DHIS data on deliveries (with no birthweight categories) and the baseline data on deliveries for PPIP (in birthweight categories). This is usually the facility manager in the MOU, and a senior administrative staff member in the hospitals. Perinatal deaths are counted and audited by the PPIP co-ordinators in Metro West. This is a team of obstetric and neonatally trained medical officers who also provide outreach and support to the community from the hospital and participate in the perinatal audit meetings at every delivery unit. This came about during a critical review of the flow of data by the PPIP Co-ordinating Committee in the Western Cape in discussion with DHIS analysts.

1.6.4.2 Child Healthcare Problem Identification Programme

Once discharged from the birth facility, neonates are no longer readmitted to neonatal units and are cared for by the paediatric health services. Neonates comprise up to seven per cent of admissions to child health facilities in South Africa (NaPeMMCo,2017:55). Neonatal deaths in child health facilities are not collected by PPIP but are reviewed by the Child Healthcare Problem Identification Programme (Child PIP).

Child PIP is a facility-based audit programme that assesses the quality of care within the paediatric healthcare facilities. The NaPeMMCo triennial report (2017) for the period from 2014 till 2016 reviewed the characteristics of neonatal admissions to child health facilities as well as the neonatal deaths that were audited by Child PIP. Neonatal deaths accounted for 9% of all child deaths collected by Child PIP. Ten per cent of neonatal deaths on Child PIP were dead on arrival at the facility and 39% died within a day of their admission. This mortality rate on the first day of admission for neonatal patients is higher than for older children (NaPeMMCo,2017:57). This may infer that the primary caregivers were not aware of the danger signs that indicated the neonate required urgent medical attention or that the care provided to a neonate in the paediatric setting was not optimal (NaPeMMCo,2017:57).

Neonatal deaths in child health facilities are more likely to capture the late neonatal deaths that are missed by PPIP. The cause-of-death profile is also likely to be different in the Child PIP group. Whereas many early neonatal deaths are due to the complications of prematurity and intrapartum hypoxia, deaths during the late neonatal period are more often related to infections (Lawn *et al.*,2014.7). The septicaemia rate amongst neonatal patients in paediatric wards was as high as 29% (NaPeMMCo,2017:56).

Child PIP also assesses the vulnerability of the patients in terms of underlying problems such as prematurity, low birthweight, nutritional status and HIV exposure. In the neonatal group 75% were assessed as having no previous background issue that would place them at risk. Only eight per cent had a history of preterm birth or of a low birthweight. But when assessed during admission to the

paediatric units, up to 48% were less than the expected weight for their age (NaPeMMCo,2011:10). This also suggests that there is a delay in health seeking behaviour by the primary caregivers.

HIV exposure has been recognised to place infants at greater risk to infectious illnesses than HIV unexposed infants even if they remain uninfected. With an HIV prevalence rate of 30% amongst pregnant women in 2017, many children are thus at risk of infectious diseases. A review by Slogrove *et al* (2016), showed that the main causes of infectious disease in HIV exposed and unexposed infants is the same but that the HIV exposed infants have more severe presentations and a higher mortality rate. This review found that during the neonatal period both HIV-exposed and unexposed neonates are susceptible to the same infectious diseases and have similar mortality rates. The peak effect on immunity by HIV-exposure between two to six months of age (Slogrove *et al.*,2016:6).

The NaPeMMCo triennial review of Child PIP (2014-2016) revealed that 68% of these neonatal deaths were avoidable (NaPeMMCo.2017:56). This suggests that there were nearly 1000 preventable neonatal deaths in the paediatric health services. The modifiable factors recognised in these cases could inform health education and programmes. Neonatal admissions to paediatric wards should be identified as high- risk admissions that require appropriate neonatal protocols and equipment.

By linking Child PIP and PPIP, the number of neonatal deaths that occur within healthcare facilities can be defined. A complete profile of neonatal mortality in the early and late neonatal period can also be defined. Furthermore, a better understanding of the full burden of disease, namely complications due to preterm birth, intrapartum hypoxia and infections, can be reached.

1.6.5 The Child Death Review

A large proportion of under-five childhood deaths (55%) in South Africa have now been shown to occur outside of healthcare facilities and are thus not entered on the PPIP or Child PIP (Mathews *et al.*,2016a: 895). Any sudden unexplained childhood deaths outside of healthcare facilities are referred to the forensic services under the Inquests Act in South Africa. The chief purpose of these referrals is to ascertain if the cause of death can be defined as natural or unnatural (Inquests Act, no 58 1959. Regulation.1960).

An unnatural death in South Africa, according to the Inquests Act 1959 (Act No.58 of 1959), is defined as a death due to physical or chemical influence or the complications thereof; an act of commission or omission which may be viewed as a criminal act; unexpected, sudden or unexplained with no apparent cause of death; or viewed as a contradiction to the Health Professionals Act. Deaths under these circumstances should be referred for medico-legal investigation (Inquest Act, no58 of 1959. Regulation. 1960).

A Child Death Review (CDR) pilot was undertaken in 2014 at two forensic pathology centres in South Africa namely Salt River Mortuary, Cape Town and Phoenix, Durban (Mathews *et al.*,2016a: 895). The primary aim was to investigate deaths in those under the age of eighteen years referred for

medico-legal investigation (Mathews *et al.*,2016a: 895). Each death was reviewed at monthly meetings attended by a multidisciplinary team of forensic pathology services, child healthcare services, law enforcement and social services in order to understand the context of the death and, identify any modifiable factors within the healthcare system and or within the home environment.

1.6.5.1 Natural Deaths

The CDR revealed that there were many children in the study (53,4%) who had died from natural causes outside of healthcare facilities who were subsequently referred to the forensic pathology services for a medico-legal opinion. In the neonatal period defined as 0-28 days, the proportion of deaths viewed to have a natural cause was 74% and included 34% who had been assessed as stillbirths (Mathews *et al.*,2016a: 898). Although incredibly important, the proportion of stillbirths should not be included with the neonatal mortality.

The main reason these deaths had been referred was as they were sudden and unexpected with no immediate explanation for a cause of death. In the infant group (less than one year of age), these are referred to as a sudden unexpected death of an infant or a SUDI. The National Health Act prescribes that a death notification cannot be completed for these instances where death has occurred outside of the facility and the child is declared dead on arrival at the health facility, the so-called DOA (dead on arrival). The CDR showed that there was a larger proportion of sudden unexpected deaths outside of healthcare facilities who were subsequently found to be due to natural causes referred to the Salt River Mortuary as compared to the Phoenix Mortuary (Mathews *et al.*,2016a: 898).

Lower respiratory tract infections (LRTI) were declared the cause of death in 30% of the child deaths in the CDR study. The impact was especially marked in the infant group (less than one year of age), where LRTIs resulted in more than half the deaths (51%). When looking at the 0-28 days group, deaths due to LRTIs appeared to be proportionately less (27,4%) but this was probably also due to the inclusion of 34% who had been defined as stillbirths (Mathews *et al.*,2016a: 898). Furthermore, the CDR also illustrated that vulnerable preterm infants were more likely to demise from RTIs in the post neonatal period (Mathews *et al.*,2016b: 851).

The CDR recognised that the diagnosis of an LRTI in the infant group during the study might have been an overestimate and a limitation of the study. The forensic pathologist may gather evidence from a full medical and social history, an external examination of the infant and the support of suggestive radiological findings taken by an Xmplar-dr x-ray (Lodox, SA) and thus make a diagnosis of an RTI (Mathews *et al.*,2016a: 898). Due to the large number of forensic cases and the ongoing burden on the forensic services, an autopsy was not undertaken on every infant especially when other findings excluded a non-natural cause.

A number of local studies exploring the role of radiology as a post-mortem tool have been undertaken. Douglas *et al* (2012) found that the radiological finding most often found in forensic paediatric cases

was opacifications and consolidation which related to lower respiratory infections. Histology was not performed in every case, but where it was, the radiological findings were in keeping with the histological findings. Quarrie and Burger (2018) undertook a prospective study to compare post-mortem lodox radiological images with histopathological findings at post-mortem at the Tygerberg mortuary in Cape Town Metro East. This study found that the lodox patterns showed low to moderate sensitivity in predicting pneumonia when compared to microscopic findings in each case. This was a smaller study sample compared to the study by Douglas *et al*, but histology was used as a gold standard in every case (Quarrie & Burger,2018:45,53). Another study in a paediatric cohort by De Lange *et al* (2007) suggests the possibility that radiological findings suggesting consolidation may be secondary to decomposition in the lungs and affected by the interval between death and the radiological examination.

1.6.5.2. Unnatural Deaths

Forty-two percent of child deaths in the CDR were deemed non-natural requiring medico-legal investigation. This was especially noted in the neonatal group where one in five neonatal deaths was either due to abandonment or murder (Mathews *et al.*,2016b: 895).

In South Africa under the Inquests Act (Act 58 of 1959), the body of a deceased *abandoned* foetus or neonate will be admitted to the forensic pathology services for a medico-legal post-mortem. The initial step is to assess viability by anthropometrical measurements. If viable, the Forensic pathologist needs to determine if there was a live birth (Du Toit-Prinsloo *et al.*,2016:571). Several methods exist to determine whether the infant breathed after birth and can thus be classified as being born alive. Most often the hydrostatic test is used during which it is assessed if the lungs float in water which is seen as a marker that there had been inspiration of air. A false positive test can also occur where there has been decomposition. In the absence of decomposition, a positive test can conclude that a live birth had occurred (Du Toit-Prinsloo *et al*.,2016:570).

The South African Police Services open a docket to investigate the circumstances around the death. The Births and Deaths Registration Act (Act 51 of 1992) prescribes that all live born neonates and all stillborn foetuses must be registered at the Department of Home Affairs. When this does not occur, the crime of concealment of birth becomes applicable under the General Law Amendment Act (Act 46 of 1935). In the case of a live birth, the neonate becomes a legal subject of South Africa and the death may be prosecuted as homicide.

The term “neonaticide” was first used to describe the killing of a neonate on the first day of life but has later been modified to include the entire neonatal period of 27 completed days of life (Hatters Friedman & Resnick, 2009:43). Subsequent studies have looked at early neonaticide which occurs in the first six completed days of life and late neonaticide from day seven until 27 completed days of life. These definitions concur exactly with the WHO definitions of early and late neonatal deaths.

Neonaticide includes active and passive means. Active means include intentional means to murder the neonate such as suffocation, poisoning, drowning and direct external trauma (Abrahams *et al.,*2016:3). Passive neonaticide occurs when the death occurs due to negligence towards the neonate, such as accidental overlaying (Abrahams *et al.,*2016:3). Abandonment of neonates, even if they are alive at the time that they are left, can also be included within this definition of neonaticide [Hatters Friedman & Resnick, 2009:43; Abrahams *et al.,*2016:3; Du Toit, Martin & Heathfield, 2018:234].

The findings of the CDR are in keeping with a growing body of evidence in South Africa that the age group from birth till four years of age are vulnerable to homicide. Prinsloo *et al.* (2011) used data from the National Injury Mortality Surveillance System (NIMSS) from 2001 till 2005 to confirm the vulnerability of children under the age of five to homicide and further found that ten per cent of the deaths in this group were due to the abandonment of neonates.

The National Child Homicide Study which followed, found the rate of neonaticide in South Africa to be as high as 19.6 per 100 000 live births (Abrahams *et al.,*2016: 10). This is notably higher than the rates in more developed settings which range from 2.1 to 6.9 per 100 000. Abrahams *et al.* (2016) looked specifically at homicide in neonates and found the majority died in the first six days of life and that abandonment accounted for 85 per cent of deaths in the neonatal period. The majority were full term with a mean gestational age of 38 weeks. Whereas mothers were the perpetrators in 71 per cent of homicides in the group younger than five years of age, they were identified as the perpetrator in all neonatal homicides (Abrahams *et al.,*2016: 10).

The few studies undertaken in other African countries confirms the vulnerability of neonates to neonaticide. A qualitative study in Tanzania estimated one of the highest neonaticide rates in the first twenty-four hours of life, 27.7 per 100 000 live births (Outwater *et al.,* 2010: 349). This study also highlighted the fact that high neonaticide rates are hidden when this period is included within under-five homicides. This is important as the reasons for homicide and the profile of the perpetrator is very different once out of the neonatal period (Outwater *et al.,* 2010: 349).

A recent study by Du Toit *et al* (2018) looked specifically at the investigation of abandoned neonates at the Salt River Mortuary from 2012 until 2016. The study population included stillbirths, non-viable foetuses and live-born neonates. Over the study period, nine per cent of cases (n=23) were determined to be unnatural. These were all confirmed to have been livebirths. Twenty-one per cent of cases (n=51) could not have a cause of death attributed and were classified as undetermined deaths. Of these undetermined cases, eighteen had been classified as liveborn but no cause of death assigned (Du Toit, Martin & Heathfield, 2018:234). These cases are often classified as undetermined by autopsy alone. The other undetermined cases could not be assessed due to the presence of decomposition or predation. This suggests that more of the undetermined cases might have been liveborn and thus potentially subject to neonaticide.

Despite the high rates of neonaticide reported, it is probably very likely that these rates are indeed underestimates as they are often mistaken as natural deaths especially in lower to middle income countries (LMICs) with fewer or strained resources where the circumstances cannot be fully investigated (Abrahams *et al.*,2016: 10). The number of neonatal deaths due to abandonment, are probably also higher in South Africa than reported by the CDR and other studies investigating this phenomenon. The majority of remains were found on open fields or in the sewage system and many might not be recovered at all (Du Toit, Martin & Heathfield.2018:234). Furthermore, the remains are often decomposed or subject to predation by animals. As a result, the forensic pathologist is unable to assess if there was a live birth or calculate the gestational age and thus viability. In the literature, these unknown or uncountable neonaticides are referred to as the 'dark number of a crime' (Tanaka *et al.*,2017:252).

Part of the procedure related to the investigation of abandoned neonates, is the collection of samples for DNA to aid in court proceedings. However, Du Toit *et al* (2018) found that a single case from their study was prosecuted with the rest either still being classified as under investigation or the investigation had been concluded and the case already closed (Du Toit, Martin & Heathfield.2018:234). It is hoped that through the monthly CDR reviews of child deaths, there will be a greater rate of prosecution or, that the numbers of abandoned neonates can highlight the need for programmes that improve contraception rates, decrease the number of unwanted pregnancies and provide support for perinatal mental health.

1.7 Avoidable or Modifiable Factors

This concept of identifying preventable deaths is quite central to the goals and objectives of ENAP and the SDGs. Through the process of mortality audit for PPIP and Child PIP as well as the multisectoral approach for audit of the forensic deaths for the CDR, the context of the death is better understood, and preventable deaths identified.

Thadeus and Maine (1994) developed the three delays model to investigate the circumstances surrounding maternal deaths. This model is now widely used in perinatal audit process, including PPIP, to determine the presence of any avoidable factors which may have made the death preventable {Waiswa, Kallander *et al.* 2010: 964; Upadhyay, Rai *et al.*2012:100}. The first delay is at the level of the individual or family and their health seeking behaviour. The second delay is the ability to access an adequate health facility and refers to transport, equipment and administrative delays. The third delay is whether the individual received adequate care at the health facility (Thaddeus, Maine. 1994: 1091). The identification of these avoidable factors is important in deciding upon health programming and policy that can ultimately diminish the number of preventable deaths.

1.8 Geographical Service Areas (GSAs) as health districts:

The Western Cape Province of South Africa has developed Health Care 2030 as a guide to aid the Department of Health achieve its vision of improved patient care. An improvement of Maternal and Child Health with a reduction in mortality, is a prioritised focus area (Western Cape Department of Health [WCDH],2014: xiv). Key health indicators have been highlighted as 'dashboard' indicators to monitor progress and inform health programmes. The ENMR and NMR are two indicators vital to monitoring neonatal survival (WCDH,2014:137).

In order to improve healthcare and community-based care, the province was divided into health districts or geographic service areas (GSAs). Cape Town Metro West is one of five GSAs in the Western Cape. Each GSA has a team of district specialists, which includes a district paediatrician, who co-ordinates care based on the progress of dashboard indicators. A service co-ordinating work group aids the district specialist to monitor these indicators, advises on the implementation of health programme interventions as well as on the outcomes (Hendricks *et al.*,2019:36). The Metro West co-ordinators for both Child PIP and PPIP provide the work group with the data they collect with regards to mortality rates as well as cause-of death and avoidable/modifiable factors in preventable deaths.

By linking the data collected by the existing audit systems conducted in PPIP and Child PIP with the neonatal deaths recorded by the Forensic Pathology Services, an accurate neonatal mortality rate could be determined. Furthermore, the causes of neonatal mortality in our GSA could be identified within the natural and non-natural spheres. The understanding of the context of the death beyond the direct biological cause through the multisectoral approach by the CDR, adds to a greater understanding and identification of avoidable or modifiable factors.

1.9 Problem Statement:

The targets for improvement of under-five mortality have not been reached as a result of a slower improvement in neonatal mortality which still accounts for a large proportion of under five deaths. Despite the rigorous system of perinatal audit of facility-based neonatal deaths by PPIP, there are other neonatal deaths that are collected by Child PIP or in the community that are referred to the Forensic Pathology Services. What is the actual NMR in the Cape Town Metro West GSA when all three mortality audit systems are linked? Could we understand more about the causes of death and identify those deaths which were preventable by linking these three mortality audit systems?

1.10 Aim

To ascertain the neonatal mortality rate for the Cape Town Metro West Geographical Service Area from January 2014 to December 2017 using the data from PPIP, Child PIP and the CDR/FPS at Salt River Mortuary, to identify the causes of death and the presence of avoidable or modifiable factors that define any of these deaths as preventable.

1.11 Study Objectives

The primary objectives of the study would be:

- To determine neonatal mortality occurring in and out of health facilities in the Metro West GSA using the Perinatal Problem Identification Programme (PPIP), Child Healthcare Problem Identification Programme (Child PIP) and Forensic Pathology Services
- To ascertain the cause of death specific neonatal mortality
- To describe the avoidable factors in each death as coded by the three audit programmes
- To make recommendations for the alignment of existing audit databases to obtain accurate neonatal statistics for the Metro West GSA

Chapter 2: Methodology

2.1 Definitions:

The following definitions are based on the International Statistical Classification of Diseases and Related Health Problems devised by the World Health Organisation (2010:151)

A **livebirth** is the complete expulsion or extraction from its mother of a product of conception, irrespective of the duration of the pregnancy, which, after such separation, breathes or shows any other evidence of life, such as beating of the heart, pulsation of the umbilical cord, or definite movement of voluntary muscles, whether or not the umbilical cord has been cut or the placenta is attached; each product of such a birth is considered liveborn.

The **neonatal period** commences at birth and ends 27 completed days after birth.

Neonatal deaths (deaths among live births during the first 27 completed days of life) may be subdivided into **early neonatal deaths**, occurring during the first six completed days of life, and **late neonatal deaths,** occurring after the seventh day but before 27 completed days of life.

Rates:

The **neonatal mortality rate** is defined as:

$$\frac{neonatal\ deaths}{live\ births}\ x\ 1000$$

The **early neonatal mortality rate** is defined as:

$$\frac{early\ neonatal\ deaths}{live\ births}\ x\ 1000$$

The **late neonatal mortality rate** is defined as:

$$\frac{late\ neonatal\ deaths}{live\ births}\ x\ 1000$$

2.2 Study setting

The Cape Town Metropole has a population of nearly two million people. Fifty two percent of the population are female and ten per cent are under the age of five (Statistics South Africa [StatsSA], 2011). It is divided into two geographical service areas. These are known as the Metro West GSA and Metro East GSA. The Metro West GSA is further divided into sub-districts of Klipfontein, Mitchells Plain, Southern and Western. Refer to the map of the Cape Town Metro Health Districts.

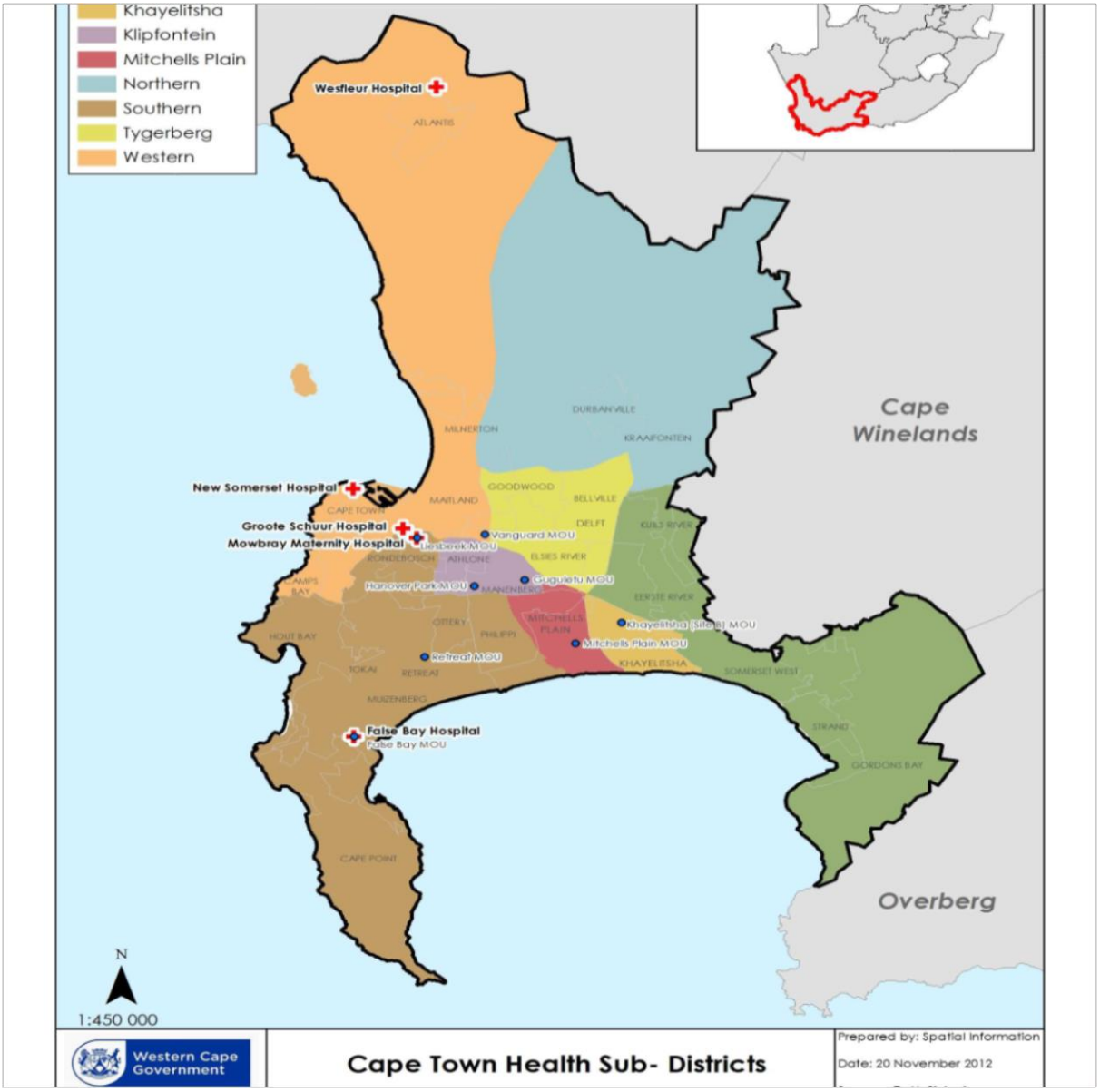


Fig 1: A map of the Cape Town Metropole Health Districts

The Maternal and Neonatal services for the Metro West GSA are well established. The tertiary services for high risk patients are provided by Groote Schuur Hospital. There are two secondary level facilities: Mowbray Maternity Hospital (MMH) and New Somerset Hospital (NSH). There are three established district level hospitals: Wesfleur (WFH), False Bay Hospital (FBH) and Mitchells Plain District Hospital (MPDH). There are seven Midwife Obstetric Units (MOUs) in the health district: Gugulethu, Mitchells Plain, Hanover Park, Vanguard and Retreat. All low risk deliveries occur at these units which are managed by midwives.

The paediatric services are also well established with clear referral pathways. Secondary and tertiary care are provided by the Red Cross War Memorial Children's Hospital (RCWMCH) and Groote Schuur Hospital. Other child health facilities in Metro West include New Somerset Hospital, Victoria

Hospital, Mitchells Plain District Hospital, False Bay Hospital and Wesfleur Hospital. The Child Healthcare Problem Identification Programme has been in use since 2009 at the RCWMCH and has been implemented at all hospitals across the GSA except for False Bay Hospital.

The Forensic services for the Metro West Geographical Service Area are based in the Salt River Mortuary. Any sudden unexplained childhood deaths outside of healthcare facilities are referred to the forensic services under the Inquests Act in South Africa to ascertain if the cause of death can be defined as natural or unnatural. As part of a mortality surveillance programme it was found that forensic data produced by the Western Cape had the lowest proportion of ill-defined deaths in South Africa (Groenewald, Bradshaw, Neethling *et al.* 2015: 115).

2.3 Study Design

This was a retrospective descriptive quantitative study that made use of existing data with regards to neonatal deaths collected by PPIP, Child PIP and CDR/FPS in the Cape Town Metro West Geographical Service Area.

2.4 Study Duration

The study included a review of data from 1 January 2014 until 31 December 2017

2.5 Study population

All neonatal deaths entered onto PPIP and Child PIP at the MOUs and hospitals in the Metro West where these programmes are implemented was recruited. Any neonatal deaths entered on Child PIP were extracted. These deaths were cross referenced with those entered on the PPIP system to ensure that the deaths were not replicated on both audit systems.

Deaths in the Metro West occurring during the neonatal period and investigated by the Forensic Pathology Service were extracted from the CDR database and included in the study.

Inclusion Criteria

A neonatal death was defined as a death if it occurred within the first 27 completed days of life.

Exclusion Criteria

A death where there had been no signs of life at birth was classified as a stillbirth and was not included in the study. Any deaths after the first 27 completed days of life was after the neonatal period and was not included.

PPIP data only includes deaths where the neonate weighs more than 500g at birth. Thus, any deaths where the individual weighed less than 500g were excluded.

In cases where the neonate was delivered outside of the Metro West GSA, these deaths were excluded.

Where the neonate was delivered in a private healthcare facility, these deaths were excluded as total delivery data used to calculate neonatal mortality rates currently do not include the deliveries made at these facilities.

2.6 Research Procedure

2.6.1 Data Collection

The total number of births and total number of live births entered on PPIP is the same data forwarded by each unit to the DHIS. These were presented for each year of the study period and in specific birthweight categories: 500-999g, 1000-1499g, 1500g-1999g, 2000-2499g, 2500g and above.

For each death, the following data was obtained: birth unit, maternal age, date of birth, date of death, birthweight, obstetric cause of death (if present), final cause of death, any avoidable or modifiable causes of death, source of data (PPIP, Child PIP or CDR). Avoidable or modifiable factors were described as health care worker associated, patient related or administrative.

These variables were exported directly from the Perinatal Problem Identification Programme (version 3.0) using the filter "Alive at birth".

The neonatal deaths captured on the Child Healthcare Problem Identification Programme were filtered using the age at the time of death being from birth till 27 completed days of life. This generated a list of paediatric folder numbers for the Cape Town Metro West GSA. For each death the following details were provided: Date of birth, date of admission, date of death, main cause of death, immediate cause of death, other cause of death, death classified as avoidable or not avoidable. For the modifiable factors coded during the audit, each folder number had to be entered on to the programme under the option of editing the information and then copied and transferred on to the original filtered list.

Clinicom was used to link the folder numbers of the neonatal deaths to the maternal folder number, to identify the unit where the delivery occurred and to provide the health care facilities where the mother and neonate had clinical folders. The maternal and neonatal folders were then retrieved from the maternity units. From these folders the data with regards to maternal age, birthweight, obstetric cause of death (if present), final (neonatal cause of death) and any avoidable factors, was collected.

All child deaths investigated by the Forensic Pathology Services at Salt River are entered onto a CDR database. Each case is identified by the WC case number. All cases identified as one month of age or younger were extracted for the purpose of this study. Where there was no detail with regards to viability or definition of the case as a livebirth or stillbirth, these cases were also extracted, to be excluded based on the post-mortem findings. The case notes were then accessed in the forensic department. These notes included a copy of the Road to Health book, police affidavits by parents or caregivers, forensic questionnaires administered by Forensic officers at the place of death and the post-mortem report completed by the Forensic Pathologist.

The clinical folder numbers obtained from the forensic case notes were also cross referenced with the PPIP and Child PIP cases to ensure that there was no duplication of deaths

2.6.2 Data Analysis

Data from PPIP, Child PIP and CDR/FPS were entered onto an Excel spreadsheet (version 2013). Please see attached spreadsheet with headings (Appendix 1). The data was transferred to Stata 14 for statistical analyses to meet with the objectives of the study.

Using the total number of live births as calculated by PPIP, the NMR was calculated for each year of the study period for each of the three data sources: PPIP, Child PIP and FPS. Cumulative mortality rates were calculated for the early and late neonatal period.

The numerical variables collected were summarised using medians or means as appropriate. Where indicated some numerical values were converted to categorical variables as they are indicated with regards to clinical practise. Means or medians were analysed using a t-test or Wilcoxon signed rank test. The categorical variables were summarised as frequency and proportions. Association between variables was tested using a chi-squared test or a Fisher's exact test. Graphs were used to display this.

2.7 Ethics, reliability, validity, generalizability:

Ethics

The study protocol was developed in line with the principles of the Declaration of Helsinki (2008) and the Department of Health's Ethics in Health Research (2004) principles, structures and processes. Ethical clearance of this study was obtained from the Research Ethics Committee of the University of Cape Town (HREC REF:274/2018) and the National Health Research Database (WC_201810_008) before the initiation of the study. Permission was obtained to access clinical folders at the health facilities and forensic folders at the Forensic Pathology Services. The data from Child PIP is on a registered database (HREC/REF:R057/2015).

The privacy of the information and confidentiality was maintained throughout the study. Each neonatal death was identified by its folder number. The neonatal deaths collected by the Forensic Pathology Services were identified by their police case numbers. Anonymity in the study was ensured especially in the light of ongoing medico-legal investigations. All data was stored on a password protected University of Cape Town desktop computer.

There is no potential harm that can be identified as an outcome of this study. All information was retrieved and saved in a confidential manner. There was no contact with family members or medical personnel. All facility deaths had been discussed anonymously in the facilities for the purposes of the monthly mortality audit meetings. Forensic deaths had been discussed by the multidisciplinary team of the Child Death Review Committee.

Chapter 3: Results

3.1 Neonatal Mortality; numbers and rates

To obtain the NMR, the number of neonatal deaths which formed part of the study (the numerator), was divided by the livebirths (denominator) and then multiplied by one thousand to obtain a rate expressed per thousand livebirths.

3.1.1 Total deliveries and total livebirths

There was a total of 137380 deliveries captured by PPIP from DHIS data in Cape Town Metro West for the study period from 2014 till 2017. Of these, 134848 were alive at the time of delivery and 2532 were stillbirths. Table 1 represents the total deliveries for the duration of the study period in weight categories.

Table 1: Total deliveries per weight category 2014-2017

	2014 (%)	2015 (%)	2016 (%)	2017 (%)	Total (%)
500-999g	578 (1,7)	589 (1,7)	477 (1,4)	498 (1,5)	2142 (1,6)
1000-1499g	665 (1,9)	622 (1,8)	581 (1,7)	622 (1,8)	2490 (1,8)
1500-1999g	1167 (3.4)	1149 (3.3)	1129 (3.4)	1138 (3.4)	4583 (3.3)
2000-2499g	3196 (9,2)	2766 (7.9)	2926 (8.7)	2808 (8.3)	11696 (8.5)
>2500g	29172 (83.9)	30080 (85.4)	28394 (84.7)	28823(85.1)	116469 (84.8)
Total deliveries	34778 (100)	35206 (100)	33507 (100)	33889 (100)	137380 (100)

(% refers to the percentage that weight category relates to the total deliveries per year)

From table 1, 15.2% of total deliveries were defined as low birthweight (LBW).

The liveborn deliveries were extracted from the total births to obtain the denominator required to calculate the NMR for this study. These are shown in Table 2 for each weight category and as a total for each year of the study.

Table 2: Total live births per weight category 2014-2017

	2014 (%)	2015 (%)	2016 (%)	2017 (%)	Total (%)
500-999g	276 (48)	320 (54)	223 (47)	211 (42)	1030 (48)
1000-1499g	543 (82)	517 (83)	478 (82)	520 (84)	2058 (83)
1500-1999g	1080 (93)	1071 (93)	1040 (92)	1047 (92)	4238 (92)
2000-2499g	3127 (98)	2695 (97)	2863 (98)	2731 (97)	11416 (97)
>2500g	29077 (99.6)	29973 (99.6)	28304 (99.6)	28747 (99.7)	116101 (99.6)
Total live births	34103(98)	34576 (98)	32913 (98)	33256 (98)	134843 (98)

(% refers to the percentage of total deliveries that were liveborn)

Fourteen per cent of livebirths are in the LBW category

3.1.2 Neonatal Deaths

A total of 977 neonatal deaths were identified from PPIP from 2014 to 2017. A single case was duplicated in the Child PIP data and excluded from PPIP as most care occurred in the paediatric setting with early referral for specialist services. Thus, leaving a total of 976 neonatal deaths (see

Table 3). A total of 79 neonatal deaths were identified from Child PIP from 2014 till 2017. The following cases were excluded from the study population:

- A single case had been entered on the PPIP and Child PIP programme
- Two cases had been duplicated on the Child PIP programme
- 17 cases had been delivered outside of the Metro West GSA and had been referred to Red Cross for tertiary specialist services
- A single case was duplicated on the CDR/ forensic data and due to the forensic nature, remained on the CDR/forensic dataset

Thus, 58 neonatal deaths (73% of the potential cases) from Child PIP were eligible for the study (see Table 3).

A total of 429 potential cases were identified from the CDR spreadsheet from 2014 till 2017. After consulting the forensic case notes, clinicom and perinatal folders, the following cases were further excluded from the study:

- 166 that were described as a month of age were older than 28 completed days of life (were less than 6 weeks old)
- 11 had been delivered at a private healthcare facility
- 20 had been delivered outside of the Metro West GSA
- 1 described as non-viable based on the legal definition of a miscarriage using a combination of anthropometric measurements
- 8 Classified as a stillbirth as there was no evidence of lung inflation associated with a live birth when the post-mortem examination was performed
- 10 were either decomposed to such an extent, or only partial remains were recovered so that it could not be determined if there had been a live birth or a stillbirth
- 2 cases where the date of delivery, and thus age, could not be determined based on a lack of documentation
- 2 cases with congenital heart disease which had been referred for forensic opinion post operatively and the cause of death determined as natural and secondary to their cardiac condition and thus captured under the Child PIP dataset for this study

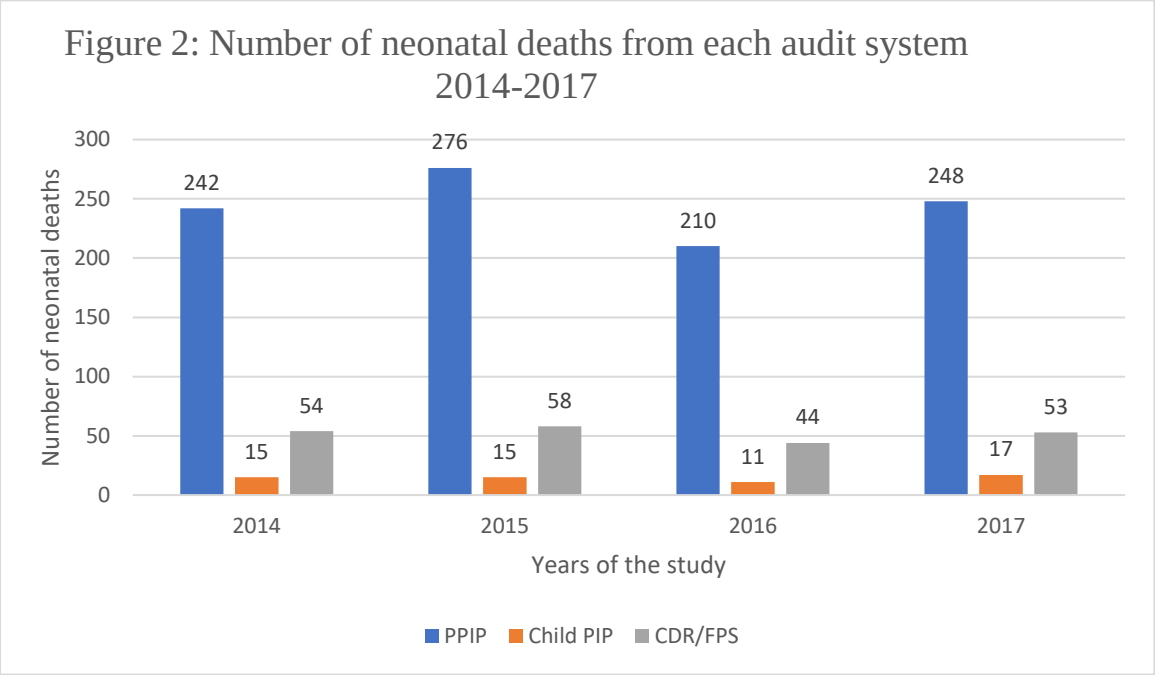
After exclusion, 209 neonatal deaths (49% of the potential cases) investigated by the Forensic Pathology Services were eligible for the study (see Table 3).

By combining the three audit systems, a total of 1243 neonatal deaths were eligible for the study. Table 3 demonstrates the number of deaths in each audit programme over the period of the study.

Table 3: Number of neonatal deaths in each audit group from 2014-2017

	2014	2015	2016	2017	Total
PPIP	242	276	210	248	976 (78%)
Child PIP	15	15	11	17	58 (5%)
CDR/FPS	54	58	44	53	209 (17%)
Total	311	349	265	318	1243 (100%)

The total number of deaths in each audit group over the study period is depicted in Figure 2 to show the proportion that each contributes annually to neonatal deaths in the GSA.



3.1.3 Neonatal Mortality

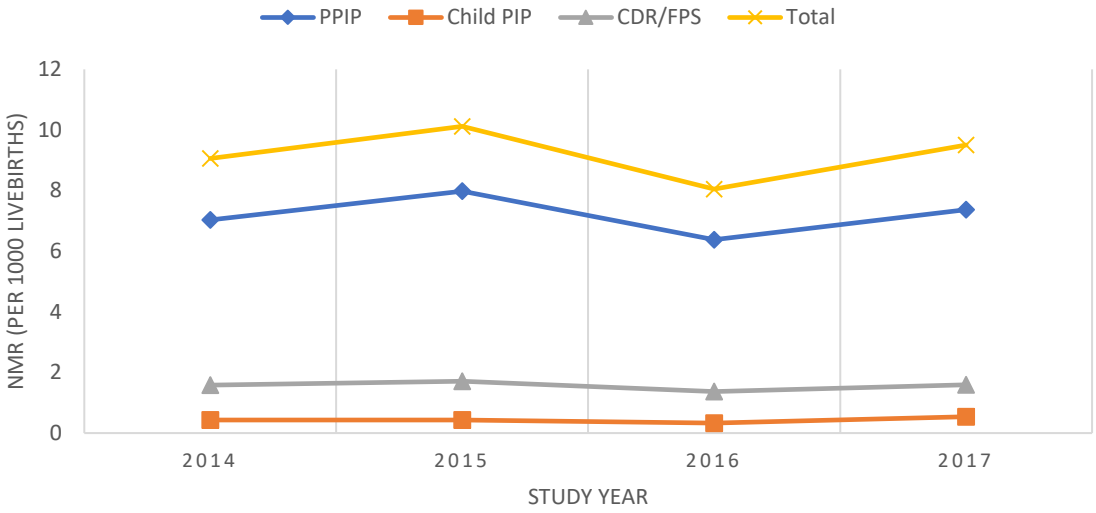
The NMR was then calculated using the total livebirths as the denominator and the neonatal deaths from this study for each year of the study. Table 4 lists the NMR per 1000 livebirths collected by each audit system 2014 till 2017.

Table 4: NMR for each data set and the total of the three 2014-2017 (per 1000 livebirths).

	2014	2015	2016	2017	Total
PPIP	7.09	7.98	6.38	7.46	7.20
Child PIP	0.43	0.43	0.33	0.54	0.43
CDR/FPS	1.58	1.71	1.33	1.59	1.55
Total	9.12	10.12	8.05	9.56	9.22

When the CDR and Child PIP NMR were added for each year to represent mortality outside of neonatal facilities, the mean over the study period was 2 per 1000 livebirths. This is illustrated further in Figure 3.

Figure 3:NMR for each dataset and total from 2014-2017



When the neonatal deaths are divided into the early and late neonatal periods, the ENMR is 7.2 per 1000 livebirths and the LNMR is 2 per 1000 livebirths

Table 5: NMR:>500g, >1000g and per weight category 2014-2017

	Born alive	PPIP NNDs	Child PIP NNDs	CDR NNDs	NMR per 1000 livebirths in the weight category
All 500g and above	134843	976	58	209	9.2
All 1000g	133813	474	57	205	5.5
500-999g	1030	502	1	4	492
1000-1499g	2058	158	5	10	84
1500-1999g	4238	77	6	23	25
2000-2499g	11416	75	12	47	12
2500g+	116101	164	28	125	2.7

From table 5 the NMR decreases when the ELBW group less than 1000g are removed from the data (9.2 as compared to 5.5 per 1000 livebirths). The NMR in this ELBW group was high at 492 per 1000 livebirths. Although not as high, the NMR in the 1000-1499g or VLBW group was high at 84 per 1000 livebirths.

3.1.4 Perinatal features of the neonatal deaths:

Perinatal factors were divided into maternal factors and neonatal factors.

Maternal Factors:

Forty forensic cases were babies were abandoned and the identity of the mother remained unknown thus there were no maternal or antenatal details available.

Maternal Age:

A total of 957 of the 976 PPIP cases had known maternal ages. Eleven per cent (n=108) were born to adolescent mothers (Age definition being nineteen years of age or younger). Sixteen per cent (n=153) were born to mothers of advanced maternal age (AMA) (greater than 35 years of age). The majority (n=696, 72.73%) were born to women aged between 20 and 34 years.

The aggregated data on maternal age showed 11% adolescent mothers and 17% to mothers of AMA.

Antenatal care

There were only seven cases from PPIP where status of antenatal care was unknown. Otherwise the greater proportion of mothers had initiated antenatal care (n=721, 74%). There were 247 cases where there had been no antenatal care initiated (25%). The status of antenatal care was unknown for twelve Child PIP cases as it was not recorded in the paediatric file or the perinatal case notes were not available. The greater proportion of known patients had initiated antenatal care (n=42, 75%). Only two mothers were known not to have initiated antenatal care in this group.

Due to the abandoned babies there is missing data amongst the CDR/FPS group. In addition, information about antenatal booking was not always noted in the forensic notes or the Road to Health Book. Thus, there are 63 cases with unknown status of antenatal care. There were 40 cases (19%) where it was confirmed in the forensic notes or Road to Health book that there was no initiation of antenatal care. It was confirmed that half the forensic cases had participated in antenatal care (n=106).

When bringing datasets together, 23% of mothers (n=289) were confirmed not to have initiated antenatal care. The presence of antenatal care is not known for 82 mothers (6%).

Maternal parity

Within the PPIP dataset, 57% (n=476) of the mother's had had at least two to four pregnancies delivered. Thirty-five per cent (n=291) fell within the primigravidae group and eight per cent (n=65) were Grand multi-gravidae. From Child PIP there were 42 cases where the parity was known. Sixty-three per cent (n=27) were multi-gravidae. Twenty-five per cent (n=11) were primigravidae and 11% were grand multi-gravidae. Of the CDR/FPS data that was available, 19% were primigravidae (n=32) and 16% were grand multi-gravidae (n=26) with the largest group being multi-gravidae (n=110, 65%).

When the datasets were brought together, nearly a third (32%) of mothers with known parity were primigravidae

HIV serology

In PPIP, 78% of mothers (n=759) had tested negative for HIV during their pregnancy. Twenty-one per cent (n=204) had tested positive or were previously known to be HIV positive. Only thirteen mother's HIV status was not known, or the results had not been available. Twenty-eight per cent of mothers (n=16) from Child PIP were HIV positive. Sixty-seven per cent of mothers (n=39) had a negative result for HIV. Only three cases had no HIV status documented for the mother. From CDR/FPS data there were 35 cases (17%) where the mother was known to be HIV positive and 95 cases where the mother had tested HIV negative during her pregnancy. Once again, there was missing data for the abandoned group of babies and others where the information with regards to HIV status was not available in the forensic notes or the Road to Health book.

When the datasets were brought together, 21% of mothers were confirmed to be HIV positive and 72% had a negative test. Seven per cent had an unknown result or the results were not available.

Syphilis serology

Ninety-four per cent of mothers (n=914) from the PPIP dataset had tested negative for syphilis during their pregnancy. Just over 4% (n=43), had tested positive. The syphilis serology was unknown or not available for 19 mothers (1.9%). The same percentage of mothers in Child PIP (n=44, 94%), had tested negative for syphilis during pregnancy. Only two mothers (4.3%) had positive serology for syphilis. Sixty-one per cent of mother (n=128) from CDR/FPS had negative syphilis serology. Five mothers (2.4%) tested positive for syphilis.

When the datasets were brought together, 88% of mothers had negative syphilis serology, 4% were confirmed as positive. The results for the remaining 8% was not available or unknown.

Table 6 summarises the maternal factors for each dataset and for the combined data.

Table 6: Perinatal factors: Maternal

	PPIP n=976		**Child PIP n= 58**		**FPS/CDR n=209**		**Total n=1243**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Maternal Age*								
13-19 years	108	11.3	3	6.4	14	9.0	125	10.8
20-34 years	696	72.7	30	63.8	109	70.3	835	72.0
>35 years	153	16	14	29.8	32	20.7	199	17.2
Antenatal care								
Unknown	8	0.7	14	21.4	63	30.1	82	6.60
No	247	25.3	2	3.57	40	19.1	289	23.25
Yes	721	74	42	75	106	50.7	869	69.91
Parity*								
Primigravidae (1)	291	3	11	25.6	32	19	334	32
Multi-gravidae (2-4)	476	57.1	27	62.8	110	65.5	613	58.8
Grand multi-gravidae (≥5)	65	7.8	5	11.6	26	15.5	96	9.2
Pregnancy*								
Single	842	86.3	49	94.23	176	97.8	1067	88.3
Multiple	134	13.7	3	5.77	4	2.2	141	11.7
HIV serology								
Unknown	5	0.5	0	0	79	36.9	84	6.8
results not available	8	0.8	3	5.2	0	0	11	0.9
Negative	759	77.8	39	67.2	95	46.1	893	72
Positive	204	20.9	16	27.6	35	17	255	20.6
Syphilis serology*								
Negative	914	93.7	44	93.6	128	61.2	1086	88.2
Positive	43	4.4	2	4.3	5	2.4	50	4

*missing data (n): Maternal age: PPIP=19, Child PIP=11, CDR=54; Parity: PPIP=144, Child PIP=15, CDR=41; Pregnancy: Child PIP=6, FPS/CDR=29; Syphilis serology: PPIP=19, Child PIP=1, FPS/CDR=76

Neonatal factors:

Timing of the deaths:

Ninety-one per cent of deaths from PPIP occurred in the early neonatal period (n=887). Child PIP (n=48, 82.8%) and CDR/FPS (n=135, 64.9%) deaths were mostly during the late neonatal period. When the three data sources were brought together this related to 78% of deaths in the early neonatal period (n= 970) and 22% (n=272) in the late neonatal period.

Birthweight:

Most PPIP deaths occurred in the low birthweight category less than 2500g (n=812, 83,2%). Many of these were extremely low birthweight (n=502, 51.4%). A smaller proportion had a normal birthweight greater than 2500g (n=164, 16.8%). The birthweight of 52 of the 58 Child PIP cases was available to the study. Of all the neonatal deaths captured on Child PIP, 41.4% (n=24) were less than 2500g at birth. Those weighing greater than 2500g made up 48.3% (n=28) of the Child PIP deaths. Forty per cent (n=84) of forensic deaths were under 2500g. A larger proportion of forensic cases were above 2500g (n=125, 59.80%).

When the three data sources were brought together, 74% (n=920) had a birthweight less than 2500g. Forty-one per cent were described as extremely low birthweight (ELBW). A quarter of the neonatal deaths were in the normal birthweight category (>2500g).

Gestational age:

Data with regards to gestational age was collected by PPIP from 2015 onwards, so there was only information for 786 of the PPIP cases (from 2015 till 2017). Of these, 83% (n=655) were born preterm, with half being extremely preterm (n=362). Gestational ages were not available in eleven of the Child PIP cases. Forty-four per cent (n= 21) of these cases were born preterm with only a single case classified as extremely preterm. Five forensic cases did not have a gestational age or anthropometry for gestational age estimation recorded in the post-mortem report. Only 37% (n=76) of the forensic cases were classified as preterm with none classified as extremely preterm.

From the study, gestational ages are recorded for 1035 of the 1238 cases. Of the known cases, 74% (n=752) are classified as preterm. The extremely preterm deaths from PPIP contribute towards 35% of the neonatal deaths with a known gestational age.

Table 7 summarises the neonatal factors for each dataset and the combined data.

Table 7: Perinatal factors: Neonatal

	PPIP n=976		**Child PIP n= 58**		**FPS/CDR n=209**		**Total n=1243**	
	n	**%**	**n**	**%**	**N**	**%**	**n**	**%**
Neonatal Age								
≤ 7 days (ENND)	887	90.9	10	17.2	74	35.1	970	78
8-28 days (LNND)	89	9.1	48	82.8	135	64.9	272	22
Birth weight*								
< 1000g	502	51.4	1	1.9	4	1.9	507	41
1000-1499g	158	16.2	5	9.6	10	4.8	173	14
1500-1999g	77	7.9	6	11.5	23	11	106	8.6
2000-2499g	75	7.7	12	23.1	47	22.5	134	10.8
2500-4400g	160	16.4	28	53.9	124	59.3	312	25.2
>4500g	4	0.4	0	0	1	0.5	5	0.4
Gestational age (WHO)*								
extremely preterm (<28weeks)	362	46.1	1	2.1	0	0	363	35.1
very preterm (28-32 weeks)	151	19.2	5	10.6	15	7.4	171	16.5
moderate to late preterm (33-<37weeks)	142	18.1	15	31.9	61	30.2	218	21.1
term (37-42 weeks)	130	16.5	26	55.3	126	62.4	282	27.2
post-term (>43 weeks)	1	0.1	0	0	0	0	1	0.1

*missing data (n=): Birth weight: Child PIP=6, Gestational age (WHO): PPIP=190, Child PIP=11, FPS/CDR=7

3.2 Causes of Death

Firstly, the causes of death for each audit system will be presented. Thereafter, these deaths will be aggregated under the causes of death.

3.2.1 Perinatal Problem Identification Programme

When all neonatal deaths with a birthweight of greater than 500g were considered, the major causes of death were (see Figure 4):

- Immaturity related (n=571; 59%)
- Congenital abnormalities (n=143; 15%)
- Hypoxia (n=139; 14%)
- Infection (n=89; 9%)
- Unknown (n=15; 1%)
- Miscellaneous category (n=18; 2%)

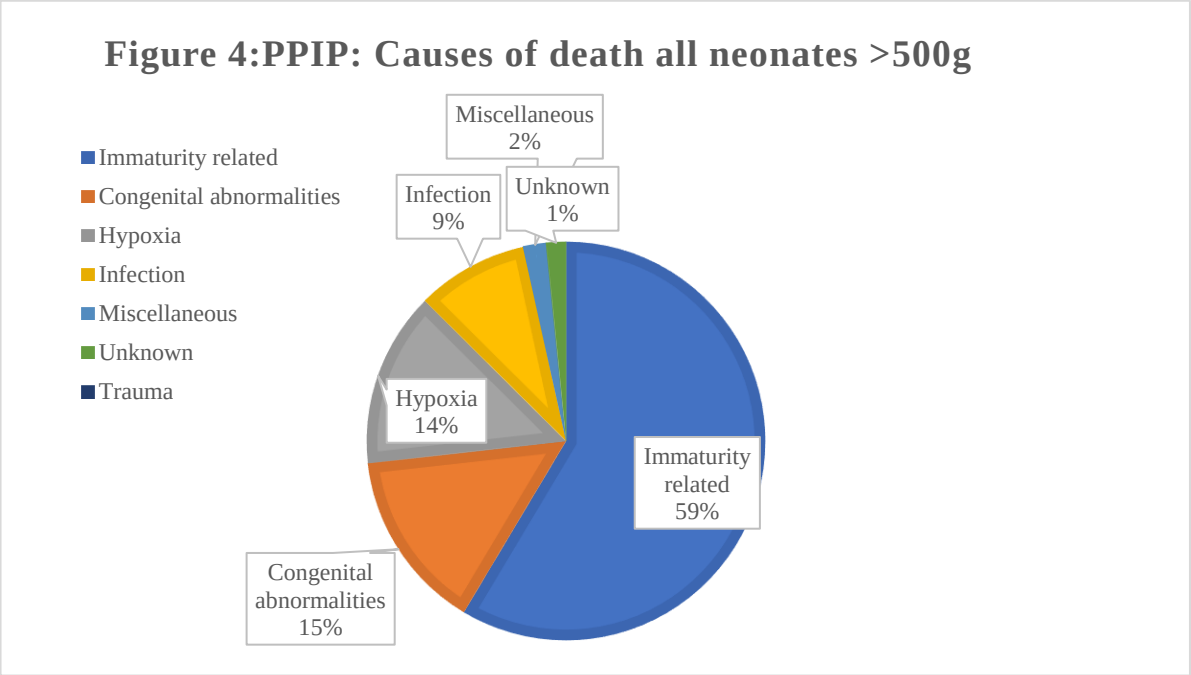


Figure 4 illustrates the proportion of these main causes of death in all neonates that are greater than 500g at birth.

Immaturity-related

Immaturity related causes included extreme multi-organ immaturity (n=447), hyaline membrane disease (n=45), pulmonary haemorrhage (n=33), necrotising enterocolitis (n=26), intraventricular haemorrhage (n=18) and other (n=1).

Congenital disorders

Congenital disorders included cardiovascular (n=31), other multiple and skeletal (n=29), chromosomal (n=22), respiratory including diaphragmatic hernia (n=22), central nervous system (n=17), renal (n=14), biochemical (n=5) and alimentary excluding diaphragmatic hernia (n=3).

Hypoxia-related

Hypoxia related deaths included hypoxic ischaemic encephalopathy (n=87), persistent fetal circulation (n=22), meconium aspiration (n=13) and other complications of hypoxia (n=13).

Infection related

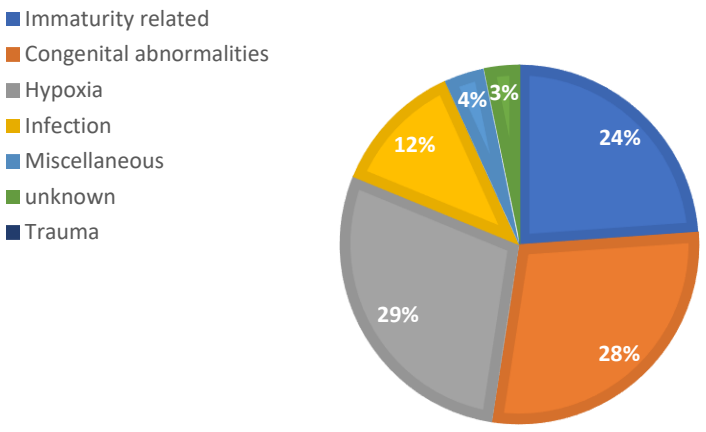
Infection related deaths included nosocomial infections (n=27), septicaemia (n=26), congenital syphilis (n=14), congenital infection (n=11), Group B Streptococcal infection (n=5), Pneumonia/lower respiratory tract infection (n=4), meningitis (n=1) and other (n=1).

Other causes

Miscellaneous category (n=18; 2%) which includes non-immune hydrops (n=8), Sudden Infant Death Syndrome (n=3), Unexplained apnoeic attacks in the first week of life (n=3), hypovolaemic shock (n=2) and other cause not classified (n=2). The trauma related category was related to subaponeurotic haemorrhages in both instances (n=2).

PPIP also reports on neonatal deaths of all neonates with a birthweight of 1000g or more. These are shown in figure 5. For this group, the contribution of immaturity related deaths was less (n=113; 24%). The major cause in the cohort of larger neonates was hypoxia (n=136; 29%) and congenital abnormalities (n=135; 28%). Infection continued to contribute towards neonatal mortality (n=57; 12%). The number of cases where there was an unknown cause of death remained the same as above but constituted a slightly larger proportion (n=15; 3%). The same applied to the category described as miscellaneous (n=17; 4%) and the birth trauma related deaths secondary to subaponeurotic haemorrhages (n=2).

Figure 5: PPIP: Causes of death all neonates >1000g



3.2.2 Child Healthcare Problem Identification Programme

The main causes of death coded by Child PIP were:

- Infection-related 51%
- Congenital disorders 27%
- Immaturity- related 14%
- Surgical 4%

The causes of death are depicted in figure 6.

Infection-related

The major causes of death from Child PIP were related to infection (n=28; 51%). These included septicaemia from a possible serious bacterial infection (n=17), meningitis (n=5), lower respiratory tract infection (n= 3) gastroenteritis (n=1) and hospital acquired infections (n=2).

Congenital disorders

Congenital disorders also featured as a cause of death amongst the Child PIP dataset (n= 15; 27 %). These included congenital heart disease (n= 8), duodenal atresia (n=2), renal abnormality (n=2), liver failure secondary to a fetal abnormality (n=2) and an inborn error of metabolism (n=1). In other cases, the congenital disorders were not coded as the main or immediate cause of death but as a contributing factor. The two cases of hospital acquired infection described above were in patients with congenital heart disease in the post-operative period, and a case of septicaemia from a possibly serious bacterial infection was also in a patient with an underlying renal abnormality.

Immaturity-related

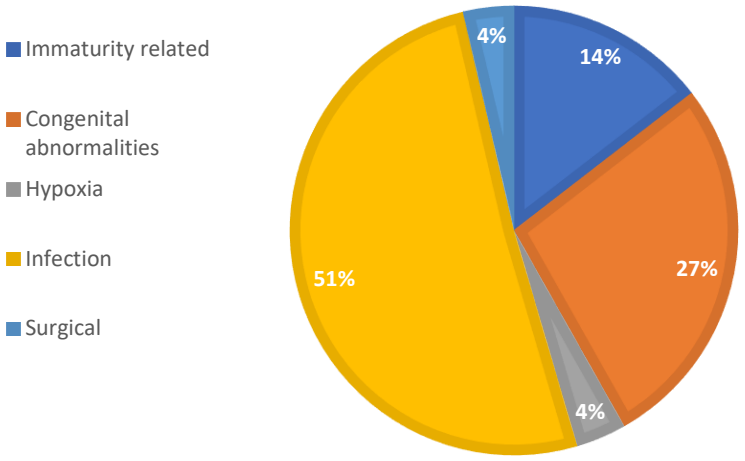
The immaturity related deaths coded by Child PIP were all due to necrotising enterocolitis (n=8; 14%). The contributing obstetric factors coded for these were idiopathic preterm labour (n=2), abruptio placentae (n=2), amniotic fluid infection (n=2) and no obstetric cause determinable (n=2).

Related to a surgical disorder

Three cases were referred to as deaths related to a surgical cause (4%). These included an incarcerated inguinal hernia, midgut volvulus and a surgical abdomen not otherwise specified by Child PIP where the folder could not be obtained (n=1).

Child PIP describes the main cause of 2 deaths as hypoxic ischaemic brain injury. (n=2; 4%) Neither of these cases are due to birth asphyxia, but due to brain injury subsequent to a prolonged cardiac arrest.

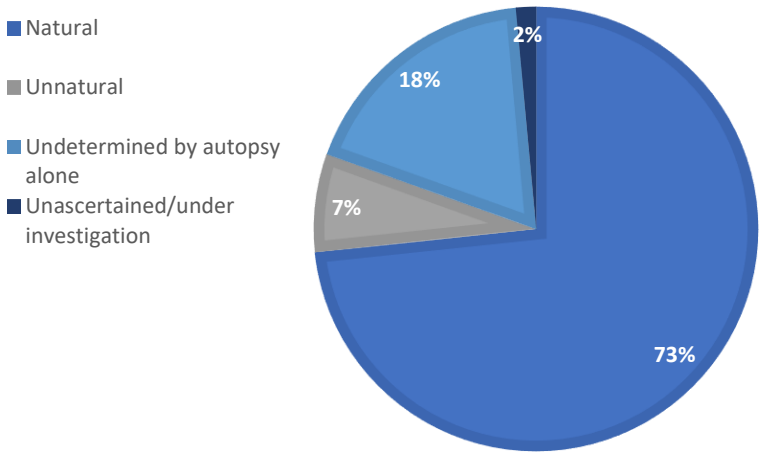
Figure 6: Child PIP: Causes of neonatal deaths 2014-2017



3.2.3 Child Death Review/ Forensic Pathology Service

The manner of death can be divided into natural causes, non-natural causes (which include accidental, suicidal or homicidal), and undetermined. Post-mortem reports described the neonatal deaths collected by the CDR as natural (n=154; 73%), unnatural (n=15; 7%), undetermined by autopsy alone (n=38; 18%). Three cases were classified as under investigation due to pending laboratory investigations. Figure 7 depicts the representation of the manner of death in the CDR dataset.

Figure 7: Medico-legal description of CDR/FPS neonatal deaths 2014-2017



Natural deaths

Seventy-three per cent of the CDR/FPS neonatal deaths (n=154) were classified as due to natural causes. These natural deaths were:

- Infection related 54,5%
- Congenital disorders 7.6%
- Immaturity-related 3.8%
- Intrapartum hypoxia 2.8%
- Related to an abdominal surgical disorder 1%

The largest group were related to infections (n=114, 54.54%). These are divided into LRTI (n=92), Gastroenteritis (n=10), Septicaemia (n=10), Meningitis (n=1) and Congenital Infection (n=1). Sixteen deaths (7.65%) were due to congenital disorders. These included congenital heart disease (n=10), imperforate anus (n=1), gastroschisis (n=1) and likely congenital syndrome or chromosomal abnormality (n=4). Eight deaths (3.83%) were immaturity related. Six deaths were secondary to intrapartum hypoxia (2.87%). Two deaths (1%) were due to surgical abdominal pathology: midgut volvulus (n=1) and incarcerated inguinal hernia (n=1).

Non-natural deaths

Sixteen deaths (7.7%) were classified unnatural. These were all acts of active neonaticide. Eleven of these cases were abandoned neonates. The description of the unnatural causes of death are listed in table 8 as described on the post-mortem report.

Table 8: Description of unnatural causes of death in CDR/FPS data 2014-2017 (n=16)

Complications of exposure	1
Drowning	2
Haemorrhage from unclamped umbilical cord	1
Ligature compression of neck and foreign body in oral cavity	1
Milk aspiration	1
Multiple injuries Severe polytrauma Severe traumatic blunt force trauma in a child whose birth was concealed Blunt traumatic injuries	1 1 1 1
Poisoning (organophosphate in this case)	1
Slit throat	1
Smothering	2
Suffocation	1
Pneumonia in a neglected, severely malnourished neonate	1

Abandoned neonates

Forty of the forensic cases were the abandoned remains of neonates. Eleven of these were confirmed to be deaths due to active neonaticide. Eleven of the sixteen confirmed cases of active neonaticide were thus abandoned neonates. Most of the abandoned neonates had a natural cause of death evident

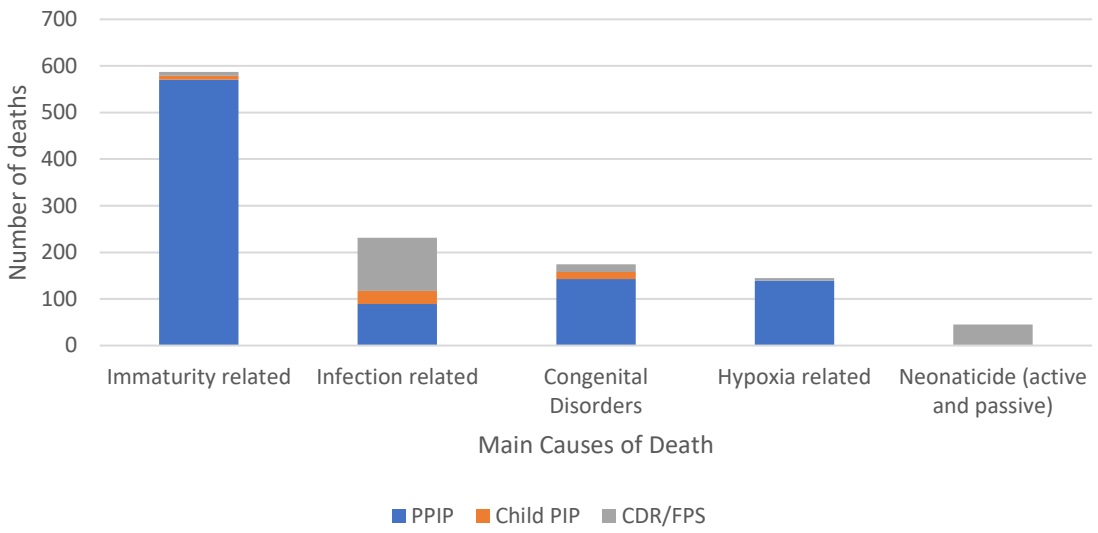
at post-mortem but it could not be determined if the neonate had been abandoned prior to its death or not. Thus, in the absence of further information, the deaths were classified as undetermined by autopsy alone. If the definition of neonaticide including passive and active neonaticide was applied and all cases of abandonment included, 19% (n=41) of neonatal forensic cases would be secondary to neonaticide.

3.2.4 Aggregated cause-specific mortality rates

The deaths in the main cause of death categories across the datasets were aggregated. Of the 1243 deaths in the study, 1137 were classified under the main causes of death. These are represented in Figure 8.

Immaturity related deaths accounted for 47 % (n=587). Infection related deaths accounted for 18.6 % (n=231). Congenital disorders contributed towards 14% (n=174) of neonatal deaths. Hypoxia related deaths accounted for 12% (n=145).

Figure 8: Main causes of neonatal deaths across the three datasets 2014-2017



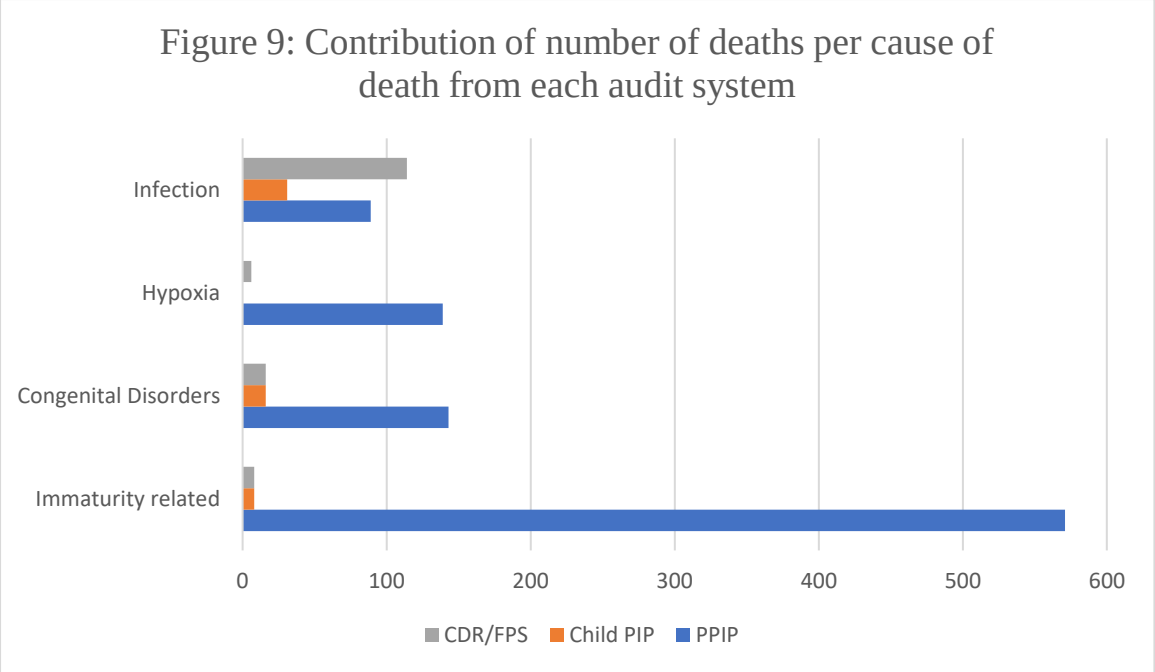


Figure 9 shows that most immaturity, congenital disorders and hypoxia related deaths were from PPIP data. The most infection related data were found in the CDR data.

When the causes of mortality of those less than 1000g were excluded, the profile changed as depicted by Figure 10. Mortality due to immaturity related causes declined and was surpassed by infection related causes, congenital disorders and then hypoxia. Neonaticide increased proportionately in comparison as all neonates in this category were greater than 1000g.

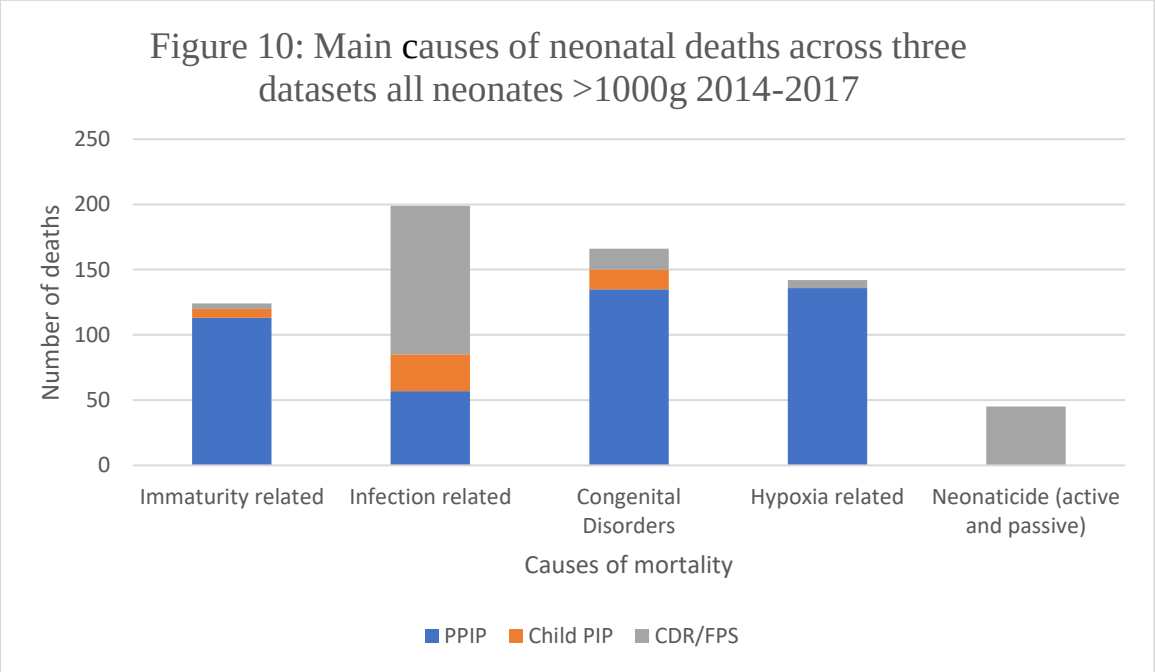
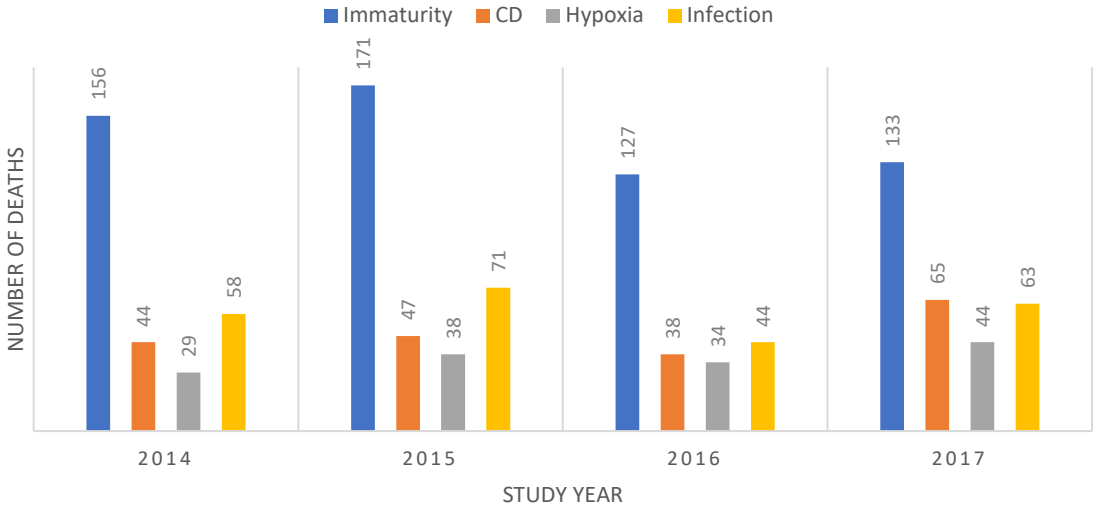


Figure 11 depicts the main causes of death per year of the study. The proportion of each cause remains similar for each year.

Figure 11: Main causes of neonatal deaths for all neonates >500g per year 2014-2017



The cause of death data was then divided into those during the early neonatal period and those in the late neonatal period

Figure 12: Main causes of early neonatal deaths across the three datasets for all neonates >500g

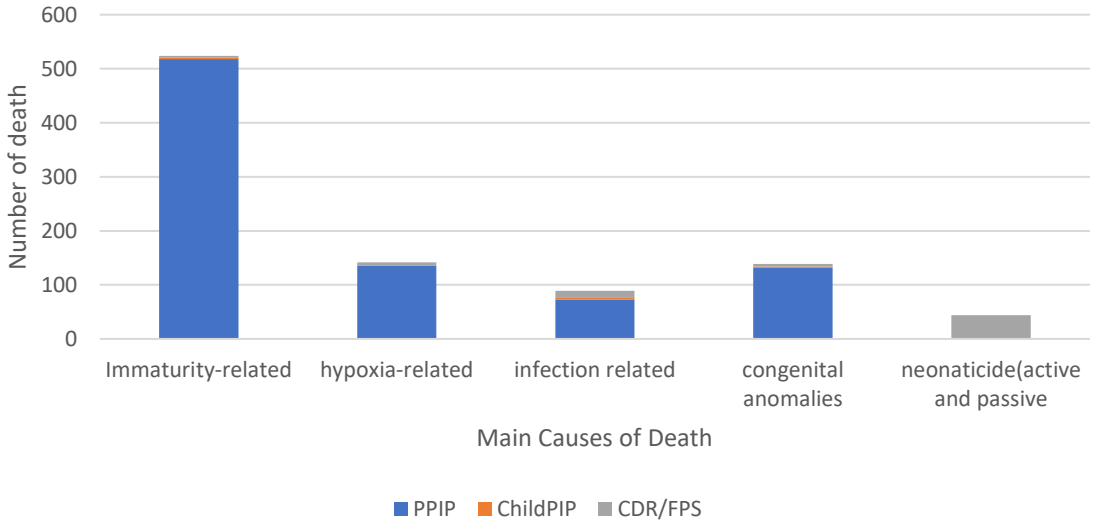
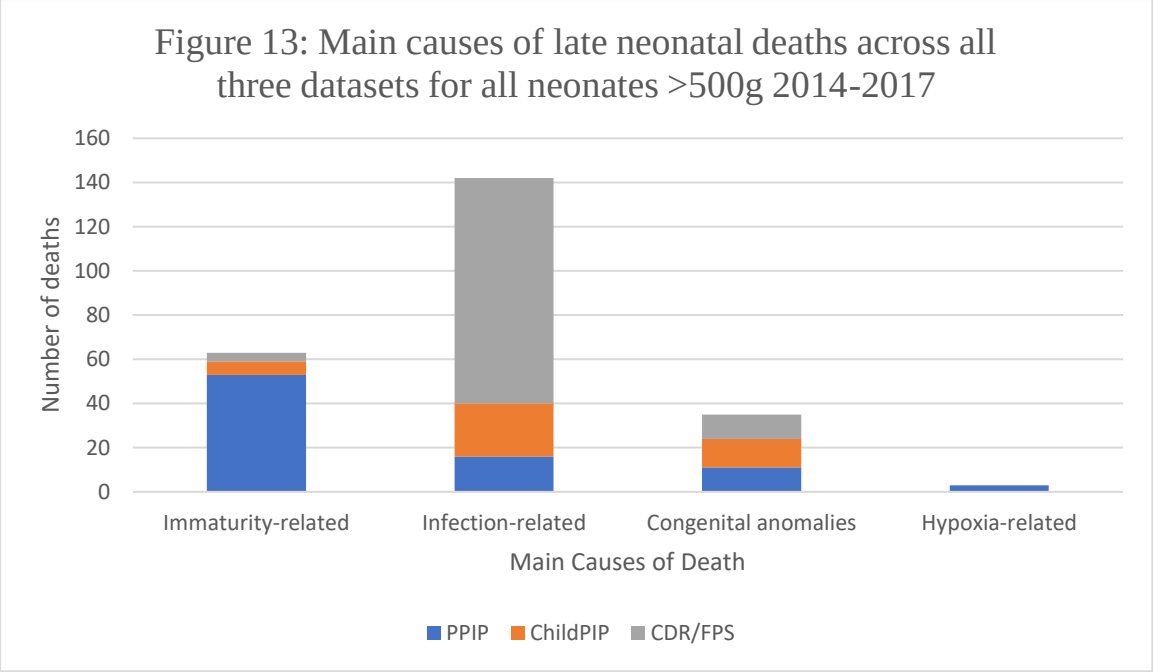


Figure 12 illustrates that the main causes of death in the early neonatal period(n=970) were obtained from the PPIP programme (n=887). Immaturity related was the greatest cause of death followed by congenital anomalies, hypoxia related and then infection related. When neonaticide included active and passive means in the early neonatal period, it contributed towards 4% of the causes of death in this period.



Infection-related deaths contributed towards 50% of all death in the late period (n=142 of a total of 272 deaths). Most of these deaths were captured by the CDR audit system. This is represented graphically in figure 13. Hypoxia related deaths were few in comparison as the majority had occurred in the early neonatal period.

3.3 Preventable neonatal mortality

3.3.1 Avoidable Factors Perinatal Problem Identification Programme

PPIP codes avoidable factors as possible or probable. For the purpose of this study, probable avoidable factors were used. Thirty-six per cent (n= 347) of the PPIP deaths were thus coded as avoidable. Figure 14 represents the proportion of the 347 deaths that were related to patient, medical personnel and administrative factors.

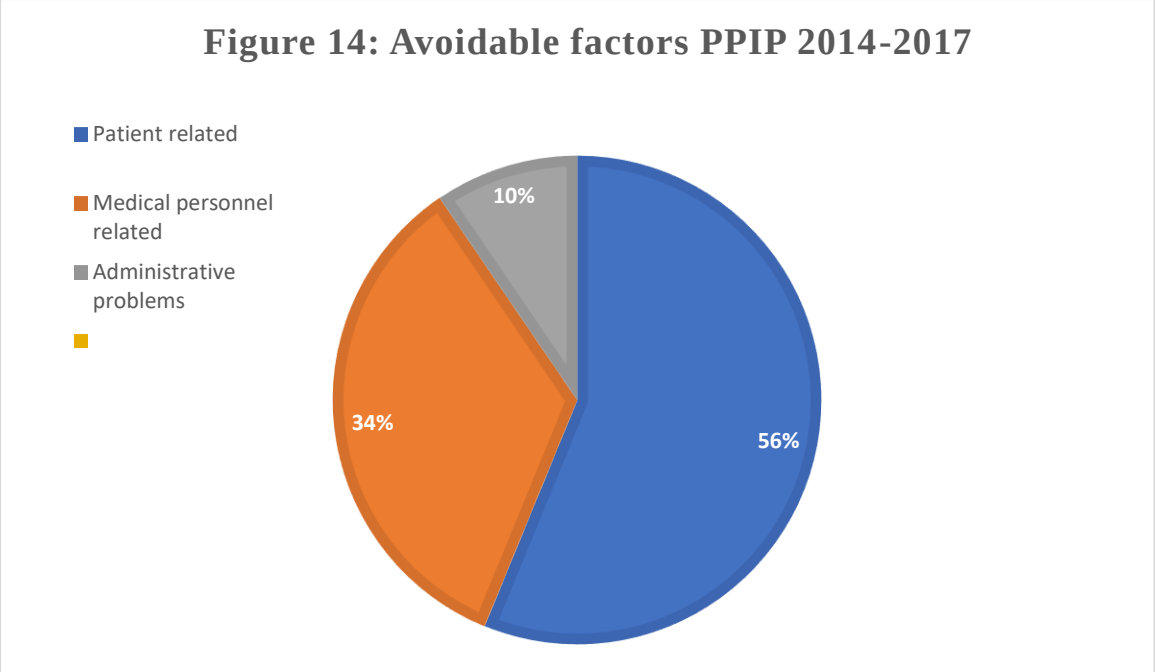
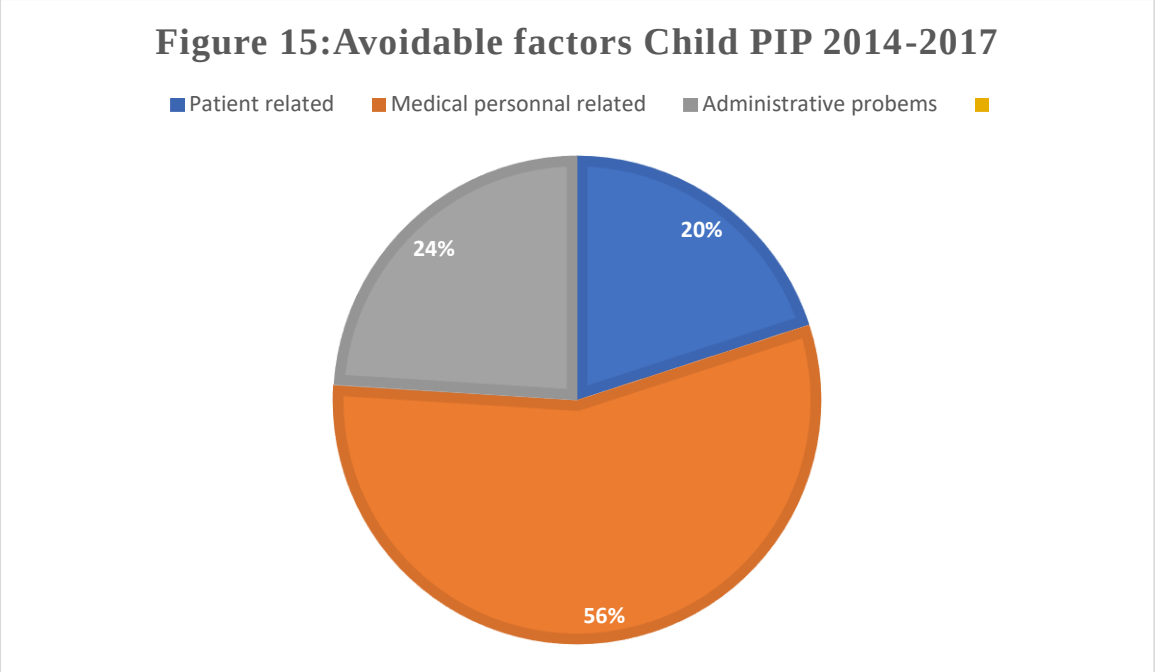


Table 9: Top avoidable factors coded PPIP 2014-2017

Avoidable factor	**Number (n=)**
Never initiated antenatal care	69
Delay in seeking medical attention during labour	38
Attempted termination of pregnancy	16
Booked late in pregnancy	15
Nosocomial infection	15
Neonatal resuscitation inadequate	12
Other medical personnel associated factors	9
Congenital abnormality not diagnosed; U/S examination was performed	8
Fetal distress not detected antepartum; fetus monitored	8
Inappropriate response to poor fetal movements	8
Alcohol abuse	7
Delay in seeking help when baby ill	7
Smoking	7
Fetal distress not detected intrapartum; fetus monitored	7

3.3.2 Avoidable Factors Child PIP

Thirty per cent (n=18) of the Child PIP deaths were coded as avoidable. Figure 15 represents the proportion of these deaths that were related to patient, medical personnel and administrative factors.



A total of twenty-five codes were used to describe the avoidable factors. Table 10 lists the avoidable factors in order of prevalence

Table 10 Top modifiable factors coded Child PIP 2014-2017

Avoidable factor	**Number of times code used (n=)**
New danger signs inadequately identified while in ward	6
Inadequate response to new danger signs	4
Inadequate monitoring and critical care equipment or consumables	3
New danger signs inadequately identified while in clinic	2
Delay in seeking help when baby ill	2
Nosocomial infection	1
Delay in going to theatre	1
Child not reassessed on departure from referral centre	1
Child not provided with adequate quantity/quality food	1
Maternal substance use	1
Never initiated antenatal care	1
Lack of standardised care and management protocols in the ward	1
Lack of intensive care and high care beds	1

3.3.3 Avoidable Factors FPS/CDR

Fifty per cent (n=104) of the neonatal forensic deaths reviewed by the CDR were avoidable. For these 104 deaths, 191 codes were used to describe the avoidable factors. Ninety per cent of the codes (n=173) used were related to patient or social related factors. Nine per cent (n= 16) were related to

medical personnel related factors and only one per cent (n=2) to administrative related factors. Table 11 lists the avoidable factors in order of prevalence.

Table 11: Top avoidable factors coded CDR/FPS 2014-2017

Avoidable factor	**Number of times code used (n=)**
Concealment of birth	41
Abandoned baby	40
Never initiated antenatal care	21
Delay in seeking help when baby ill	14
Infanticide (active)	12
Maternal substance use	11
Delay in seeking medical attention during labour	7
Previous SUDI	7
Baby managed incorrectly at Hospital/clinic	7
Possible health systems failure	6
No skilled attendant present in labour	4
Maternal neglect	3
Attempted termination of pregnancy	2
Declines admission for personal/social reason	2
Defaulted ARVs	2

Chapter 4: Discussion

4.1 Introduction

The SDG target is to attain an NMR of less than 12 per 1000 livebirths by 2030. By current PPIP data, this might have already been achieved in this GSA. Other parallels that could be drawn are with other high middle-income countries who are achieving NMRs as low as 5 per 1000 livebirths.

This study is a situational analysis of the state of neonatal survival in our GSA in the early years post the MDGs. The objectives aim to count all neonatal deaths occurring both within and outside of healthcare facilities. It is hoped that a greater understanding of causality and preventable mortality can assist with a blueprint going forward to improve neonatal survival optimally.

4.2 Neonatal Mortality

The results of this study show that in order to obtain an accurate estimate of neonatal mortality at a district or GSA level, accuracy is required in determining the number of live births (denominator) and neonatal deaths (numerator). While in this study PPIP captured 78% of the deaths, it needed to be complemented by the data from Child PIP and CDR that accounted for 5% and 17% of the deaths, respectively. This was important in determining the true neonatal mortality rate (NMR) in the GSA. Hence, it is estimated that the NMR in Metro West for the period under review ranged from 8.1 to 10.1 per 1000 live births which is higher than previously reported by PPIP alone (6.4 to 8 per 1000 live births). In terms of achieving the goals of the Every Newborn Action Plan and making every death count as well as improving the NMR of the GSA, this is a significant addition (Mason *et al.,*2014:2). The findings of this study have implications for other GSAs in the Province and beyond where the NMR has been based mainly on the PPIP data.

While most deaths occurred within the healthcare facilities, 16% of the neonates died at home. There were three groups within this population: the sudden unexplained deaths (SUDIs), those presenting as dead on arrival to health care facilities (DOAs) and those who were abandoned. The largest group were the SUDIs comprising nearly 60% of all these deaths that have been described as the “fed, bed and dead” group (Mathews et al, 2016b:852) with many factors contributing to these deaths. The DOAs making up the second group and comprising 20% of the deaths and 3% of all the deaths, may not be referred for forensic examination if suspected of dying from natural causes although this does not appear to be the case in the Metro West GSA where forensic post-mortem examinations are recommended to exclude non-natural causes of death (Mathews et al, 2016b:853). The third group whose unidentified bodies were found abandoned in various sites accounted for 20% of all the neonatal deaths. It is noteworthy that this number may be an underestimate of the neonatal deaths that occur in this manner, as the distinction between still birth and neonatal deaths was not possible even after autopsy was performed and not all of abandoned bodies may be found or found before

decomposition. The undercounting in the latter group has been referred to as the "dark number" (Tanaka *et al.*,2017:252).

There were key features characterising the neonatal deaths included in the study cohort. Most of the deaths (78%) were early neonatal deaths occurring within the healthcare facilities; these deaths were mainly captured by PPIP while Child PIP and CDR captured the late neonatal deaths. This emphasizes the need to bring the audit systems together to understand mortality during the entire neonatal period and comply with the principles of the Every Newborn Action Plan in terms of accurate counting of every death. Seventy-four percent of the babies who died were low birth weight and 73% were preterm. The overall low birthweight rate which has remained persistently at 14% nationally is an indicator of the socio-economic and health status of the community in general (Medical Research Council [MRC], 2001:4). The higher risk neonates included in the low birthweight category were the preterm and appropriate size for gestational age (AGA), as well as the growth restricted neonates, who were small for gestational age (SGA). Growth restriction can be secondary to fetal, placental and maternal factors. Important biological maternal factors include poor maternal weight gain during pregnancy and low BMI, pre-existing chronic diseases and the onset of pregnancy related conditions such as eclampsia. Further important socio-economic factors include; low socio-economic status, poor household food security, low education status, decreased birth intervals and smoking. Fetal causes refer to multiple pregnancies and congenital disorders (Tibrewala, Tibrewala &Tibrewala,1980:27). LBW(<2500g) infants are forty times more likely to die in the neonatal period than neonates with a normal birthweight (>2500g). Furthermore, the risk of morbidity and mortality increases yet again in the preterm infant when they are growth restricted and SGA {Singh et al.,2009:11; Katz *et al.*,2013:417}.

There are several maternal features implicated in neonatal mortality in this study. Advanced maternal age (>35 years) was evident in 16% of the mothers in this study which is consistent with national (Watcham, Schon & Christianson,2007.1064) and global data (Laopaiboon *et al*,2014:49). Advanced maternal age increases the stillbirth rate and the risk of perinatal mortality (Laopaiboon et al,2014:49). These could be due to the increased likelihood of pre-existing medical conditions in women of AMA, as well as the increased risk of chromosomal abnormalities (Laopaiboon *et al*,2014:50). A South African study compared pregnancy outcomes in women between the ages of 20 and 34, with those above 34 years and found significantly higher rates of preterm delivery (19% vs 14%) and LBW (28% vs 19%) than in younger women ($p<0.05$). Although not found to be significant in that study, there were more complications of labour such as breech delivery and the need for caesarean section in women of AMA (Hoque, 2012: available online). Studies in Sub-Saharan Africa show that AMA and high parity remain prevalent, and often co-exist, as women continue to bear children until they reach menopause (Health Communication capacity Collaborative,2014: 10). The factors that govern this are

multiple and include access to contraception, cultural norms, religion, polygamy rates, early marriage and marital instability and the perceived advantage of many children (Ndiaye, et al,2018:370).

Most mothers in this study had an average of 3 children. Almost a third, however, were primigravidae. The first pregnancy is recognised as higher risk for multiple reasons. Often there is a higher rate of pregnancy related complications such as pregnancy induced hypertension with increased severity and progress to eclampsia. There is a higher rate of intrauterine growth restriction with eventual fetal loss or neonates that have a low birthweight (Alewi, 2016:3). Grand multiparity (five or more) is also a higher risk pregnancy. Nine per cent of this study population were grand multipara. A systematic review of grand multiparity showed the risks to be mostly to the mother, especially for post-partum haemorrhage. There is an increased risk of macrosomia of the neonate as well as meconium stained liquor. But interestingly, despite the increased risk of a low Apgar score at five minutes, the risk of perinatal mortality is less in grand multipara (Yves *et al,*2006:25).

The data collected by this study refers only to the presence of any antenatal care and not necessarily to the number of visits nor to the skill of the antenatal care accessed. This study could confirm at least one antenatal visit for 70% of the mothers in the study cohort. Six per cent remained unknown as the information was not recorded in the folders or, in the case of the abandoned neonates, where no maternal information was available. A way forward would be to understand the reason why 24% of the mothers who had neonatal deaths did not initiate antenatal care but also to assess the number of antenatal visits in those who accessed antenatal care. Antenatal care is an important aspect of a healthy pregnancy by ensuring adequate health and nutrition of the mother and preparation for labour and the postnatal period. Adequate antenatal coverage is recognised to decrease both maternal and neonatal mortality (Dowswell *et al.,*2010). UNICEF data shows that 86% of pregnant women accessed antenatal care globally in 2019. Southern Africa had a lower coverage rate of 52%. At the beginning of the millennium, the goal was for every woman to attend an antenatal clinic at least once. Initial research by the WHO promoted a reduced visit antenatal care plan in efforts for antenatal care to be more accessible to lower income countries (Villar *et al.,*2001). However, it became apparent that the initial data showed increased perinatal mortality where the number of visits had been decreased (Dowswell *et al.,*2010). The initial recommendation of at least four visits was increased to at least eight visits to increase surveillance and diminish missed opportunities. This antenatal care package is referred to as 'Basic Antenatal Care Plus' in South Africa (Hofmeyr &Mentrop,2015:904)

The third National HIV seroprevalence study (2012) found a national seroprevalence rate of 12.2% (95%CI:11.4-13.1). The Western Cape had the lowest prevalence with a seroprevalence rate as low as 5.2% in the Cape Town Metropole (Shisana *et al.*2014:47). In 2019 the National antenatal sentinel study was released looking specifically at antenatal seroprevalence. It showed that the national antenatal seroprevalence rate in 2017 had remained stable at 30.7% (Woldesenbet *et al.,*2019:23). The Western Cape remained the province with the lowest prevalence at 15.9% (95%CI:14.2%-17.8%)

(Woldesenbet *et al.*,2019:24). This contrasts to this study that found a confirmed HIV seroprevalence of 21% in this cohort of mothers who had suffered a neonatal loss in this GSA. This could in fact be higher as in 7.5% of mothers, the HIV result remained unknown or was not recorded.

The effects of HIV in the perinatal period are multiple. Mothers that are HIV positive are more likely to have a preterm and low birthweight neonate. Furthermore, the use of antiretroviral therapy in the antenatal period is now also linked to an increased risk of prematurity (Boer *et al.*,2007:148). HIV exposed neonates are at a higher risk of necrotising enterocolitis and intraventricular haemorrhages, both recognised complications of prematurity, as well as an increased chance of mortality, than the HIV unexposed neonate. A local study undertaken at GSH confirmed that preterm, VLBW (<1500g) neonates that are HIV exposed are at a higher risk of these adverse outcomes as compared to the unexposed cohort (Riemer *et al.*,2019).

While the focus has been on neonatal mortality, the still birth rate cannot be ignored as it relates to the perinatal mortality rate. Approximately two per cent of the deliveries during the study period were stillbirths. The SBR is an important indicator as it reflects the quality of antenatal and intrapartum care in the health service. The resultant stillbirth rate (SBR) for the period was 18 per 1000 total deliveries which compares favourably to the rate for South Africa. For a similar period to the study, 2014 till 2016, the rate was 21 per 1000 total deliveries (NaPeMMCo,2018:15) The SBR of lower income countries are as high as 45 per 1000 total deliveries which is in stark contrast to the rates of high-income countries which are as low as 5 per 1000 total deliveries (MRC, 2017). The data from this study also shows the great burden amongst the ELBW group where 52% were stillborn. In comparison 0.4% of births with a weight greater than 2500g were stillborn.

4.3 Causes of neonatal deaths:

The second objective of the study relied upon the details surrounding the neonatal deaths that are collected by the three audit programmes included in the study. This information created a broader context within which to understand mortality and, through the assessment of cause specific mortality, appropriate interventions and programmes could be identified.

The South African national PPIP data from 2014 till 2016, which included the extremely low birthweight group, showed the four main causes of death to be: immaturity (48%), hypoxia-related (24%), infection-related (11%) and congenital disorders (9%) (NaPemCo,2018). The local PPIP data from the GSA indicated causes of death to be immaturity (59%), congenital disorders (15%), hypoxia-related (14%) and infection-related (9%). This data suggests an epidemiological shift as infection related causes have diminished proportionately and congenital disorders have increased. When the deaths from the three audit systems, including the large group of extremely low birthweight neonates, was brought together however, the main cause of death remained immaturity-related (47%) followed by infection-related causes (19%), congenital disorders (14%) and then hypoxia (12%).

Neonatal deaths due to immaturity and its complications remain the major cause of neonatal mortality worldwide in both developing and developed countries (Kalimba &Ballot,2013:13). Not only is prematurity the leading cause of mortality amongst neonates, it is becoming one of the leading causes of under-five mortality as well (Harrison & Goldenberg,2016:74). Even in settings where the neonatal mortality rates are decreasing, deaths due prematurity have been noted to remain relatively static or proportionately more in some cases (Liu *et al.*,2012). In this study, 97% of the deaths attributed to immaturity were collected by PPIP. The few from Child PIP were preterm infants referred for surgical management at RCWMH for necrotising enterocolitis.

The reasons for preterm delivery are multiple and often unknown. Maternal risk factors include: a history of a previous preterm delivery, gestational hypertension and eclampsia, maternal smoking, poor maternal nutrition and certain infections especially urinary tract infections and chorioamnionitis. In many cases of spontaneous preterm labour, the cause remains unknown (Harrison & Goldenberg,2016:74).

Preterm deliveries may increase in settings where there is epidemiological transition, as in many middle-income countries. A study in such a country, Brazil, followed three cohorts of mothers and neonates in 1982, 1993 and 2004 found that preterm delivery rates and low birthweight rates increased over the period, despite improved antenatal and neonatal care. The study suggested that this was in large part due to the termination of pregnancies for maternal or neonatal health conditions without accurate early ultrasounds and high caesarean section rates (Barros *et al.*,2005:853). This concept is now referred to as provider-initiated preterm delivery. Comparisons show that mortality is higher in this group than in cases where there was spontaneous preterm labour (Souza *et al.*,2016:1). Neonatal mortality rates in Brazil remained constant at 10 per 1000 livebirths, mostly in part due to improved neonatal care (Barros *et al.*,2005:853).

In the South African context, parallels could be drawn with the Brazilian study due to the high burden of gestational hypertension (1 in 10 pregnant women) and diabetes that may complicate pregnancies and require induction of labour (Noubiap *et al.*,2019). Moreover, the high seroprevalence of HIV in pregnant women, may also result in more inductions of labour, particularly in preterm prelabour rupture of membranes.

Previous studies looking at mortality in the extremely low birthweight group in South Africa have illustrated that survival in this group is low, particularly in low resourced settings. Two studies in Johannesburg (Gauteng, South Africa) hospitals found survival rates to be around 34% where the ELBW neonates were nursed in a high care setting but without access to back-up mechanical ventilation (Kalimba& Ballot,2013:13). A study in the Cape Town Metro East GSA at Tygerberg hospital showed a 63% short term survival rate where they had surfactant, nasal CPAP and back up mechanical ventilation (Kirsten *et a*l.,2012:952). A further outcome of these studies was to highlight

significant interventions to improve survival in the ELBW group are antenatal care, antenatal steroids and the prevention of necrotising enterocolitis (Kalimba & Ballot,2013:13) (Ballot *et al.*,2010).

The important difference between these studies was access to back up ventilation which becomes highly relevant in low resourced settings. In order to allocate resources appropriately, a viability document was developed in the Western Cape province. These guidelines regulate access to surfactant, ventilation in a high care setting (nasal cannula oxygen or CPAP) or in an ICU setting (IPPV or oscillation). Criteria are based on gestational age and birthweight. These guidelines also stress that in the likely case of the delivery of an ELBW neonate, transfer to a delivery facility with neonatal ICU facilities before delivery is critical (Western Cape Province Department of Health,2019:1). This is also based on findings in the Metro that show better short-term outcomes for neonates that are 'inborn' at neonatal ICU facilities versus those that are 'outborn', delivered at MOUs, home or during transfer (Gibbs, Tooke & Harrison,2015:900). Importantly part of this process addresses the supportive care for the management of those ELBWS who are not expected to survive (Western Cape Province Department of Health,2017:1)

A further relevant feature of studies investigating survival of ELBW neonates is the definition of this group. PPIP defines this group as less than 1000g whereas other studies have defined the group as less than 900g (Kalimba & Ballot,2013:14) (Ballot *et al.*,2010) (Kirsten *et al.*,2012:952). Gestational age is also an important factor governing survival especially in the peri-viable group. In developed settings there has been improved survival for neonates around 26 weeks of gestational age. In less developed settings, birthweight is used as a surrogate for gestational age especially where there is poor access to antenatal care or resources such as early ultrasound scanning (Katz *et al.*,2013:417).

When the ELBW deaths were excluded in this study, the main cause of death was infection related deaths, closely followed by congenital disorders and then hypoxia, and then followed by immaturity. Previous studies with regards to cause of death specific rates in the neonatal period have noted that infection related deaths usually become more prevalent in the late neonatal period, particularly in low income countries (Oza *et al.*,2015:23). Half of the late neonatal deaths in this study were due to infection related causes. These late neonatal deaths were mostly captured by the CDR or Child PIP datasets.

The timing of onset of neonatal sepsis or infection is a useful tool in determining aetiology. Early onset sepsis is a bacterial infection acquired by the neonate before or during delivery. Late onset sepsis is acquired after delivery and may be a source in the hospital environment (nosocomial) or community acquired. There are many definitions of early versus late onset of sepsis. In this GSA early onset sepsis is before 72 completed hours of life. Specific bacteria and with differing antibiotic sensitivity are associated with early and late onset sepsis. The neonate is thus treated accordingly and

in keeping with locally prevalent organisms and appropriate antibiotic therapy (Simonsen *et al.*2014:21).

Of particular importance in this study are the number of deaths due to pneumonia that occurred outside of health care facilities in the late neonatal period. Reid *et al* (2016) illustrated this phenomenon in the Metro West GSA in the under-5 group where 88% of deaths due to pneumonia occurred outside of healthcare facilities. This is in comparison to high survival rates when cases of pneumonia were treated as an in-patient. Of concern is that 15% of the cohort that died in the community had been taken to the healthcare services by caregivers in the week preceding their death. It has been suggested that pneumonia as a cause of death, be separated from other causes of neonatal sepsis, to highlight this as a cause (Oza *et al.*,2015:19).

Models of epidemiological progression have illustrated that as countries improve their socioeconomic circumstances, deaths due to infections decrease and non-communicable diseases and diseases of lifestyle become more prevalent. In the neonatal period, after an initial decline in congenital disorders due to factors such as improved maternal nutrition, congenital disorders become more prevalent (Christianson *et al.*,2006). Initial PPIP data suggested that the GSA might have made such a transition. However, this study reveals that infection related deaths are still more prevalent than deaths due to congenital disorders when the other audit systems are included.

PPIP data shows that congenital disorders continue to contribute towards neonatal mortality both nationally and in the GSA (9% and 14% respectively). The prevalence of congenital disorders at birth is not always accurate or available as these are often misdiagnosed or remain undiagnosed (Malherbe *et al.*,2016:142). This is illustrated by the number of congenital disorders diagnosed at post-mortem in the CDR data. The prevalence of congenital cardiac disease is of interest especially in the light of resource allocation to antenatal ultrasound for congenital anomalies and mandatory pulse oximetry screening of neonates at birth facilities before discharge. Pulse oximetry screening of neonates has proven benefit in detecting critical congenital heart disease which lead to death in the neonatal period if not managed. A study looking at the feasibility of pulse oximetry at a unit in the GSA suggested that screening could be implemented successfully (Van Niekerk *et al.*,2016:817).

This study's findings with regards to neonaticide are in keeping with those of the CDR pilot study where 25% of neonatal deaths from the FPS were attributable to neonaticide (Mathews *et al.*,2016: 898). Active and passive neonaticide impact mortality rates in the early neonatal period and affect the larger neonates in this study. In almost all cases, the mothers were not identified and there was no data available with regards to maternal factors such as antenatal care or HIV serology.

4.4 Preventable deaths

An important component of improving perinatal survival is to interrogate those deaths that are avoidable and to employ approaches that address these avoidable factors. For the purpose of this

study, the three delays model were used during the perinatal audits of the deaths in the facilities and applied to the notes of the CDR for each of those deaths. Avoidable factors were sought in the neonate's home environment, in the healthcare facility and other administrative areas which included transport and availability of on-site tests and equipment.

Approximately a third of the neonatal deaths in the neonatal and paediatric facilities were coded as probably avoidable. Nearly half of the CDR deaths were coded as avoidable. The prevalence of deaths due to abandonment either by passive or active neonaticide contributed towards the higher proportion of preventable deaths in the CDR group.

When the three audit systems were merged, 469 deaths or thirty-eight per cent of study deaths had been coded as avoidable. This is a large portion of the deaths and if these could be prevented would have a marked impact on the NMR. If this is applied to the mean NMR for the study period of 9.2 per 1000 livebirths, the NMR would be 5.7 per 1000 livebirths. This NMR would be very comparable to those of other high middle-income countries such as Bulgaria and Brazil.

For the purpose of reporting, the most prevalent avoidable factors were reported in each audit system as likely areas where the greatest change could be affected. It is worthwhile to evaluate these within the context of resource allocation and within the ambit of effective, yet simple measures proven to be of benefit in ENAP.

4.4.1 Patient related factors

The Committee on Morbidity and Mortality in Children report (2014) found that 30% of modifiable factors stem from the home environment. This report lists factors such as health seeking behaviour, the ability to recognise danger signs of severe illness and adequate nutrition. This delay in health seeking behaviour and the identification of severe illness is clearly shown in the top avoidable factors listed in all three datasets. This includes: no antenatal care, irregular attendance of antenatal care, delay in seeking attention in labour, delay in seeking medical attention when a child is ill.

The presence of antenatal care has been proven to be of benefit in maternal and neonatal survival but remains the most often coded probable avoidable factor in PPIP. As previously mentioned in this discussion, further quality of antenatal coverage should also include monitoring the number of antenatal visits. Furthermore, timeous presentation in labour can also allow for the administration of antenatal steroids or referral to an appropriate level of care for both mother and neonate. Further qualitative research could interrogate why antenatal care or care in labour is not always sought or attended regularly in a metropolitan GSA where there is high accessibility. Factors such as the prevalence of gang violence, substance use, safe and dependable transport and job security have been mentioned in this authors experience. Factors such as these could further be included in coding of avoidable factors by the audit programmes in this study.

The CDR data provided much context surrounding neonatal deaths occurring at home or on route to a healthcare facility. Most of these deaths were sudden and unexpected. There were also cases where the child had been noted to be ill but a subsequent delay in seeking help contributed toward the neonate's death. Many of these were classified as dead on arrival at a health facility. Parental or caregiver education with regards to the identification of signs of severe illness in neonates is paramount. In the study some of these included pyrexia, seizures and cyanosis.

Abandonment and neonaticide is referred to as one of the least preventable crimes (Du Toit *et al.*,2018). This is complicated by the fact that very few cases lead to prosecution. The follow up study undertaken at the Salt River Mortuary of abandoned neonates from 2012 till 2016 confirmed that only one case had been prosecuted. Even though DNA evidence is taken at post-mortem, this often does not lead to the identification of the biological mother. This makes it difficult to profile mothers who are at risk of abandonment or active neonaticide. High abandonment rates have been linked to communities where there are many unwanted pregnancies and illegal abortions (Du Toit *et al.*,2018). Effective family planning and improved education may be effective as primary prevention. Other strategies would be access to legal and safe terminations of pregnancy or of safe havens where babies could be taken after delivery and placed in protective care in a confidential manner.

Despite improved access to termination of pregnancy (TOP) in accordance with the South African Choice of Termination (CTOP) Act (1996), there are still many women who seek illegal TOPs. This was illustrated by the number of cases in PPIP of neonates delivered preterm after an illegal TOP attempt and subsequently dying due to immaturity related reasons. It is unknown what proportion of the abandoned neonates might have been delivered after illegal TOP attempts. Local qualitative studies have noted that many women do not access safe TOP services due to a fear of stigma, concern about a lack of privacy and negative, judgemental behaviours displayed by healthcare personnel. A further qualitative study noted that those women who are turned away due to concerns about the gestational limits and reasons for abortion, a high proportion access illegal abortions or traditional healers to self-induce labour (Harries *et al.*,2015). Once again community education and empowerment might improve access to safe services.

The Western Cape has the highest rates of alcohol and other illicit substance abuse (methamphetamines, cannabis, opiates and amphetamines) in South Africa as well as the world (Stein *et al.*,2007). The effect of alcohol on the developing foetus and Fetal Alcohol Spectrum disorder are known and include growth restriction and behavioural issues (Stratton *et al.*,1996). Illicit drugs may result in preterm birth, low birth weights, neonatal abstinence syndrome as well as complications such as abruptio placenta that result in perinatal hypoxia. Social complications include the need to be placed in protective or foster care due to neglect (Johnson *et al.*,2003:187).

A study undertaken at eleven Midwife Obstetric units in the Cape Town metropole confirmed that although alcohol is the most commonly used substance by pregnant women, methamphetamine ("tik") remains the most commonly used illicit drug (Petersen Williams *et al.*,2014:8). The South African Community Epidemiology Network on Drug Use project further found that methamphetamines are the most prevalent primary substance of addiction. When the use was compared between non-pregnant or pregnant women, it was also found to be more often used by pregnant women (Dada *et al.*,2011). Methamphetamines use in pregnancy is associated with several neonatal complications such as microcephaly, growth restriction and increased risk for admission to the neonatal ICU. Preventive measures suggested by research include urinalysis as early as possible in the antenatal period. This is suggested as substances such as methamphetamines have been proven to be under reported on simple history taking at MOUs in this GSA and the opportunity to initiate interventions is then potentially lost (Petersen Williams *et al.*,2014:8)

Steps to diminish preventable deaths require appropriate resource allocation and are affected by the prevailing socio-economic conditions. The SDGs highlight the importance of psychological and socio-economic upliftment to attain healthy individuals and communities. This is evident in the number of goals set within these spheres.

To this end, the First Thousand Days initiative was launched by the Western Cape Government through the Department of Social Development. This programme highlights the period from pregnancy until the child's second birthday as a critical period to achieve optimal health, so that the child may "survive and thrive". There are three sentinel aspects. Firstly, nutrition and growth monitoring are key aspects of health. Secondly, it is integral for those in primary caregiving positions to be able to provide nurture and support. And, thirdly, a safe environment is important so that the caregiver can provide appropriate stimulation for development.

4.4.2 Healthcare personnel related

Healthcare personnel related avoidable factors are identifiable in the antenatal, intrapartum and neonatal categories. It is imperative to recognise these during perinatal audit. The aim is not to assign blame but to inform ongoing staff education and processes that may adversely affect the outcome of neonates and improve survival.

It is important to recognise that the neonate differs from the older paediatric patient in several ways. The routine observations differ, and values need to be known in order to identify danger signs. The identification of abnormal observations as a precursor to an eventual collapse and death was noted in Child PIP data. Several CDR deaths due to sepsis, pneumonia and meningitis were noted to have occurred despite the caregiver having taken the neonate to a healthcare facility. Recurrently it was observed that neonates with pyrexia were sent home on oral antibiotics and paracetamol. The

recommendation remains that neonates with pyrexia be referred to hospital for a septic screen and be initiated on appropriate intravenous antibiotics (WHO,2015:1).

The WHO has designed protocols for management of a possibly serious infection in young infants (PSBI) specifically so that healthcare personnel are aware of the different approach to young infants. The approach to pyrexia is defined until day 59 of life (WHO,2015:1). It is important that protocols such as these which are present in paediatric facilities, be visible to any healthcare personnel who may treat neonates.

Another difference from paediatric management pertains to resuscitation of the neonate. The resuscitation logarithm differs. This is also key knowledge for those working with neonates. Appropriate equipment is also essential. Programmes to improve knowledge of airway management such as 'Helping Babies Breathe' have been rolled out in the Metro. Ongoing resuscitation training and access to equipment is important. At RCWMH, neonates are now admitted to specific wards to ensure that they receive appropriate care.

Late onset neonatal sepsis (>72 hours after birth) is acquired in the hospital or in the community. Healthcare personnel and their knowledge of handwashing and contact precautions are integral in preventing nosocomial infections. This is a very simple and cost-effective way of decreasing infection. Remembering also, that hospital acquired infections often include microorganisms with antimicrobial resistance (Vergagno *et al.*,2005:220).

PPIP coded congenital abnormalities that were not detected antenatally. The opportunity to detect abnormalities antenatally assists in secondary prevention through screening, antenatal diagnosis as well as the option to medically terminate the pregnancy. Tertiary prevention could also be applied through diagnosis and the option to treat the congenital abnormality surgically or provide appropriate care and treatment. Many congenital abnormalities can be cured after a single surgical procedure and others may survive with some disability (Malherbe *et al.*,2016:143).

The system of post discharge care of the high-risk neonate is well established in the Metro West GSA. On discharge from the units the discharge plan and clear recommendations for follow up are placed in the Road to health booklet. It is important that the healthcare worker explain the importance of these appointments subsequent to discharge. This is also an opportunity to involve the Community based services in the observation of the neonate in the home environment.

4.5 Limitations

This study attempts to achieve accuracy in the counting of neonatal deaths in the GSA. There are several points where there may have been undercounting. The neonates that are dead-on-arrival to healthcare facilities may not always be referred for a forensic opinion. A notification of death form is then submitted and ultimately recorded on VR data. Reassuringly, the CDR study found that forensic referrals are more likely to be done to the Salt River mortuary in this GSA as compared to the other

mortuary, Phoenix (Kwazulu Natal), in the study (Mathews *et al.*,2016: 898). Furthermore, Bamford *et al* (2018) showed the Western Cape to have the least discrepancy between VR data and DHIS data (0.7%). A comparison of this data with VR findings would be of interest.

The abandoned neonates, referred to as the dark number of homicides in this text, have several effects on accuracy (Tanaka *et al.*,2017:252). It is unknown if the birth was counted at a facility. At least one case was recognised in the CDR as having a hospital identification band. So, it is unknown what component of the denominator of neonatal mortality they form. Further, there are abandoned neonates that are not found, as previously mentioned in this thesis. So, the numerator of neonatal mortality is also affected. From the CDR notes and the follow up study on abandoned neonates at Salt River Mortuary, the identities of the mothers remained unknown, only a single case was identified and prosecuted (Du Toit, Martin & Heathfield, 2018:234). Thus, it is not possible to obtain information about maternal factors such as antenatal care or HIV serology and to code avoidable factors specific to each death.

This cohort only investigates the public healthcare system. Inclusion of neonatal deaths from the private healthcare system would expand the neonatal healthcare profile for the GSA. Medico legal cases in the private healthcare setting would be collected by the CDR. A comparison with VR data may also expand upon the private healthcare system as deaths would be reported to the DHA.

Twenty per cent of the neonatal deaths that might have been part of this study were excluded. Nearly half of the CDR cases and a quarter of the Child PIP deaths were excluded. Although these deaths were excluded, these cases illustrate some salient aspects of our population in this GSA which need to be considered when attempting to count every death

Firstly, 40% of the cases from the CDR database that had been captured as a neonate were excluded because they were older than 28 days and therefore not eligible. This subset would need further investigation. The incidence of vulnerable preterm infants within the cohort who died at home soon after discharge from hospital from LRTI, is noteworthy. An investigation into this group who were older than 28 days might also elaborate on the higher neonatal mortality rate reflected in the South African Demographic Health Survey included babies who were 3 days beyond the neonatal period (birth to thirty-one days of life.)

Secondly, there were neonatal deaths in the GSA of neonates born in other health districts. The urbanisation of South Africa's population with subsequent migration or movement of people, particularly in the post-Apartheid era, is well recognised. Projected figures suggest that at least 60% of our population will be living in urbanised environments by 2030 (Collinson, Tollam & Kahn, 2007:78). Recent South African studies suggest that this process is not simple but a more gradual process from rural to semi-urban, from town and then to metropolitan centres. There is still a high prevalence of intraurban moves that occur. Four per cent of the cases from Child PIP and CDR data

were excluded as they had been delivered outside of Metro West. Places of delivery were as close as the Metro East drainage area and others as far as Beaufort West or George. This study unequivocally shows this phenomenon within the health districts where mothers and families are seen moving in and out of drainage areas.

The corollary might suggest that there are neonatal deaths that were not counted as the death might have occurred outside of the Metro West drainage area. This would be further supported by current research about the migration pattern of South Africans. Counter urbanisation is now a recognised phenomenon which may occur in two instances: children are sent to live with family in rural areas as the parents are working long hours in urban or metropolitan areas without the support of family, and, adults become too unwell to work as a result of HIV/AIDS and return to family in rural areas (Collinson, Tollam & Kahn, 2007:78).

The large number of deaths due to immaturity in the ELBW group within healthcare facilities is notable. It is also appropriate that these neonates be within facilities. In comparison, there are very few ELBW deaths recorded by the CDR. There may be incongruency in viability or inclusion criteria between the facility audit systems and forensic services. In PPIP a birthweight of more than 500g and signs of life at birth would result in inclusion. The FPS uses foot-length measurement and may not always have an accompanying history to confirm if there were signs of life. Moreover, in such cases a lung expansion test may not be performed or may offer inconclusive results. These cases are then either defined as miscarriages or not determined.

The prevalence of pneumonia deaths, particularly in the late neonatal period in the community, is alarming. The CDR study also noted this as a potential limitation (Mathews *et al.*,2016a: 898). The diagnosis is in part based on a suggestive clinical history and radiological findings. A post-mortem examination is not always undertaken as there are large workload strains on the forensic pathology services. The literature with regards to the use of radiological tools to diagnose LRTIs seems to be equivocal and the recommendation by many researchers is to use it in conjunction with macroscopic and microscopic findings.

This study does not present the primary obstetric cause of death for the cohort. This information is included in the PPIP data. Although able to link most Child PIP cases to a maternal folder, the CDR data did not always offer a folder number for the neonate to link to the maternal folder. Detail surrounding avoidable and modifiable factors was included in the Child PIP and CDR data, which was critical in collecting this data. Future research should include obstetric causes associated with neonatal deaths.

4.6 Recommendations

- Classify deaths as neonatal deaths in keeping with the WHO definition of 28 days of life
- Identify neonatal deaths by this classification in Child PIP and CDR data

- Report neonatal deaths as a specific group within Child PIP and CDR
- Consolidate data from three audit systems by unification of datasets required by each dataset
- Include antenatal factors in Child PIP and CDR cases
- Include maternal cause of death if relevant or possible from Child PIP or CDR
- Include CDR neonatal data in the *Saving Babies* as the Child PIP data has already been

4.7 Conclusions

The burden of deaths due to immaturity remains high and not unexpected where 41% of neonatal deaths are ELBW. Current viability criteria are aimed at optimum use of resources and may improve survival amongst this group, particularly in the group that would have better short term and long-term neurodevelopmental outcomes.

High risks for a poor neonatal outcome include a primigravid mother, HIV exposure, a low birthweight (especially ELBW) and prematurity. Quality of antenatal care should look at the number of visits attended and not just a single attendance. Ideally all ELBW and VLBW neonates should be delivered at a secondary or tertiary unit and not 'outborn'.

Appropriate antenatal care and timeous presentation in labour would allow for the implementation of the simple measures outlined in ENAP such as antenatal corticosteroids, treatment of maternal and neonatal infections, attendance by a skilled healthcare personnel in labour and appropriate neonatal resuscitation. Postnatal care with support of KMC and breastfeeding, would assist in timeous recognition of neonatal sepsis. A postnatal care plan that is robust in the neonatal period and continues until the first 6 week visit to the municipal baby clinics may potentially improve survival ('survive') as well long-term outcomes ('thrive').

Infection related deaths were shown by this study to have a greater burden than expected from current PPIP data as these were mostly derived from Child PIP and CDR data. This would suggest that the epidemiological transition which was thought to be occurring in the GSA has not occurred or has been slowed by other factors. Pneumonia deaths still predominate and have a large out of hospital mortality. Especially relevant in pneumonia is the health seeking behaviour of caregivers and the ability of healthcare providers to recognise potentially serious bacterial infections in neonates and refer appropriately.

The suggested limitation that LRTIs are over-diagnosed in the forensic setting should be explored. The FPS faces large workload pressures, particularly in the light of unnatural deaths in the South African context. Resource allocation may enable the service to perform more post-mortem examinations on presumed LRTI to confirm the diagnosis and even elucidate the microorganism and microbial resistance profile.

Also, where 10% of neonatal deaths are sudden unexpected deaths (SUDIs), a better understanding and definition of this group is urgently required. Many of these deaths were subsequently found to be secondary to lower respiratory infections. This would imply that caregivers are not always aware of danger signs. This also emphasizes the need for improved education provision to the community with regards to danger signs, to improve health seeking behaviour.

It is further relevant that where a fifth of CDR deaths and 3% of all study deaths were due to active and passive neonaticide, that this entity be monitored and investigated. Especially, as this may be an underestimate. Prevailing socioeconomic conditions, access to TOP services or other options of tertiary prevention such as adoption or safe havens should be explored.

The study showed that the GSA has achieved the SDG for NMR of less than 12 per 1000 livebirth. However, a mean NMR of 9.2 per 1000 livebirths is not comparable to those of other Upper middle-income countries. But where 38% of the deaths were coded as avoidable, appropriate programmes to address these factors could diminish preventable deaths and bring the NMR to as low as 5.7 per 1000 livebirths.

A strong recommendation from this study is the importance of unifying data from the three active audit systems looking at neonatal mortality and auditing the causes of death and avoidable factors in this health district or GSA. These could be used to inform ongoing measures by the district healthcare services to improve outcomes. Such measures would include community education and empowerment, healthcare personnel training and awareness. Further qualitative research into health seeking behaviour in our communities would be of great benefit. Support of measures taken to align care with those of ENAP and ongoing integration of the social and health aspects of the First Thousand Days, are integral.

List of References

Abrahams N, Mathews S, Martin LJ, Lombard C, Nannan N, Jewkes R. 2016. Gender differences in homicide of neonates, infants, and children under five years in South Africa. Results from the cross-sectional National Child Homicide study. PLoS Med. 13(4):c1002003. doi:10.1371/journal. Pmed.1002003

Alewi O. 2016. Comparing the outcome of Early and Late Antenatal Care (ANC) among Primigravidae patients in Klerksdorp, South Africa. A Survey Approach. *South American Journal of Public Health.* Available online at https://pdfs.semanticscholar.org/7d44/fa6c000dc409020f5a5f05ed7c4555c6db34.pdf. (Accessed September 2019)

Ballot DE, Cooper PA. 2010. Determinants of survival in very low birth weight neonates in a public sector hospital in Johannesburg. *BMC Pediatrics* 10:30. Available online http://www.biomedcentral.com/1471-2431/10/30 (Accessed December 2019)

Barros FC, Victoria CG, Barros AJD, Santos IS, Albernaz E, Matijasevich A, Domingues MR, Sclowitz IKT, Hallal PC, Silveira MF, Vaughan JP. 2005. The challenge of reducing neonatal mortality in middle-income countries: findings from three Brazilian birth cohorts in 1982, 1993, and 2004. *Lancet* 365:847-854.

Bamford LJ, McKerrow NH, Barron P, Aung Y. 2018. Child Mortality in South Africa: Fewer deaths, but better data are needed. *SAMJ suppl 1*.108(3) 25-32.

Barrosa C, Lichuma W, Mason E, Lehohla P, Paul VK, Pkhakadze G, Wickremaranthne D, Yamin AE. 2016. Accountability for women's, children's and adolescents health in the Sustainable development Goal era. *BMC Public Health* 16 (suppl 2):799: 27-29.

Bhutta Z, Das JK, Bahl R, Lawn JE, Salam RA, Paul VK, Sankar JM, Blencowe H, Rizvi A, Chou VB, Walker N. 2014. Every Newborn 3: Can Available interventions end preventable deaths in mothers, newborn babies, and stillbirths, and at what cost? *Lancet Series Every Newborn Study Group.*384:347-370.

Births and registrations Act 51 of 1992.Regulation.1992. Government gazette. 14182. 1 October. Proclamation No 79. Pretoria. Government Printers. Available online at https://www.gov.za/documents/births-and-registration-act

Boer K, Nellen J, Patel D, Timmerman C, Tempelman C, Wihaut M. 2007. The AmRo study: pregnancy outcome in HIV-1-infected women under effective antiretroviral therapy and a policy of vaginal delivery. *BJOG* 114(2):148-155.

Bradshaw D, Chopra M, Kerber K, Lawn JE, Bamford L, Moodley J, Pattinson R, Patrick M, Stephen C, Velaphi S. 2008. Every death counts: use of mortality audit data for decision making to save the lives of mothers, babies, and children in South Africa**.** *Lancet*, 371(9620)**:**1294-1304.

Bradshaw D, Dorrington R, Laubscher R. 2012. Rapid Mortality Surveillance Report 2011. Cape Town: South African Medical Research Council. http://www.mrc.ac.za/bod/RapidMortality2011.pdf (accessed October 2018).

Christianson A, Howson CP, Modell B. 2006. Global report on Birth defects, the hidden toll of dying and disabled children. White Plains New York: March of Dimes Birth Defects

Foundation. Available online http://www.marchofdimes.org/materials/global-report-on-birth-defects-the-hidden-toll-of-dying-and-disabled-children-full-report.pdf

Committee on Morbidity and Mortality in Children: Second triennial report of the Committee on Morbidity and Mortality in Children under 5 Years (CoMMiC). 2014. Pretoria: National Department of Health.

Collinson MA, Tollan SM, Kahn K. 2007. Migration, settlement change and health in post-apartheid South Africa: Triangulating health and demographic surveillance with national census data1. *Scand J Public Health (Suppl)*. 69: 77-84. doi:10.1080/14034950701356401

Child PIP Group & Medical Research Council. 2011. Child Healthcare Problem Identification Programme version 3.1: Training and Reference Manual.

Dada S, Pluddemann A, Parry C. 2011. Monitoring alcohol and drug abuse trends in South Africa. SACENDU *Research Brief* 14(2): 1-16).

De Lange C, Vege A, Stake A. 2007. Radiography after unexpected death in infants and children compared to autopsy. *Paediatric radiology* 3(2):159-165.

Dorrington RE, Bradshaw D, Laubscher R, Nannan N (2018). Rapid mortality surveillance report 2016. Cape Town: South African Medical Research Council. ISBN: 978-1-928340-30-0.

Douglas TS, Fenton Muir N, Kewana K, Ngema Y, Liebenberg L. 2012. Radiological findings at a South African forensic pathology laboratory in cases of sudden unexpected death in infants. *SA Journal of Radiology* 16(1)

Downe S, Finlayson K, Tuncalp O, Metin Gulmezoglou A. 2015. What matters to women: a systematic scoping review to identify the processes and outcomes of antenatal care provision that are important to healthy pregnant women. *BJOG* 123(4): 529-537. Available online at https://doi.org/10.1111/1471-0528.13819

Dowswell T, Carroli G, Duley L. 2010 Alternative versus standard packages of antenatal care for lowrisk pregnancy. Cochrane Database System Rev 2010, Issue 10. Art. No.: CD000934. Available online at http://dx.doi. org/10.1002/14651858.CD000934.pub2]

Du Toit C, Martin LJ, Heathfield LJ. 2018. Investigation into abandoned neonates admitted to the Salt River Forensic Pathology Mortuary, Cape Town. *Forensic Science International.*292:232-241. https://doi.org/10.1016/j.forsciint.2018.09.031.

Du Toit-Prinsloo L, Pickles C, Smith Z, Jordaan J, Saayman G. 2016. The medico-legal investigation of abandoned foetuses and newborns- a review of cases admitted to the Pretoria Medico-Legal Laboratory, South Africa. *Int J Legal Med.*130: 569-574. doi 10.1007/s00414-015-1198-y.

General Law Amendment Act 46 of 1935. Available online at https://www.gov.za/documents/general-law-amendment-act-14-may-1935-0000.

Gibbs L, Tooke L, Harrison M. 2017. Short term outcomes of inborn v. outborn very-low-birth-weight neonates (<1500g) in the neonatal nursey at Groote Schuur Hospital, Cape Town, South Africa. *SAMJ* 107(10): 900-903.

Groenewald P, Bradshaw D, Neethling I, Martin LJ, Dempers J, Morden E, Zinyakatira N, Coetzee D. 2016. Linking mortuary data improves vital statistics on cause of death of children under five years in the Western Cape Province of South Africa. *Tropical medicine and International health.*21(1):114-121.

Groenewald P, Azevedo V, Daniels J. 2015. The importance of identified cause-of-death information being available for public health surveillance, actions and research. *SAMJ* 105(7): 528-530. Available on https://doi.org/10.7196/SAMInew.8019 (Accessed April 2019).

Harries J, Gerdts C, Momberg M, Greene Foster D. 2015. An exploratory study of what happens to women who are denied abortions in Cape Town, South Africa. *Reproductive Health* 12:21. Available online https://reproductive-health-journal.biomedcentral.com/track/pdf/10.1186/s12978-015-0014-y . Accessed January 2020.

Harrison MS, Goldenberg RL. 2016. Global burden of prematurity. *Seminars in Fetal and Neonatal Medicine* 21(2):74-79.

Hatters Friedman S, Resnick PJ. 2009. Neonaticide: Phenomenology and considerations for prevention. *International Journal of Law and Psychiatry.*32: 43-47. Available on https://doi:10.1016/j.ijlp.2008.11.006. (Accessed March 2019)

Health Communication Capacity Collaborative (HC3). 2014. Engaging families for healthy pregnancies: family planning for women of advanced maternal age and high parity: global evidence on health outcomes and secondary analysis of DHS data from two countries in West Africa. Baltimore, MD: John Hopkins Centre for Communication Programmes.

Hendricks MK, Hawkridge A, Jacobs L, Evans J, Mahomed H, Linley L, Westwood A. 2019. Tracking progress on the health status and service delivery outcomes for neonates and children in the Metro West geographic service are of the Cape Metropole, 2010-2015. *S Afr J Child Health* 13(1): 36-43. DOI:10.7196/SAJCH.2019.v13i1.1581.

Hoque ME. 2010. Advanced maternal age and outcomes of pregnancy: A retrospective study from South Africa. *Biomedical Research* 23(2). Available online at https://www.alliedacademics.org/articles/advanced_maternal_age_and_outcomes_of_pregnancy (Accessed September 2019)

Hofmeyr GJ, Mentrop I. 2015. Time for "Basic Antenatal Care Plus" in South Africa? SAMJ 105(11): 902-904. DOI:10.7196/SAMJ.2015.v105i11.10186

*Inquests Act 58 of 1959.*1960. Regulation as amended 1996. Available online at https://www.gov.za/documents/inquests-act-3-jul-1959-0000. (Accessed 29 November 2018).

Johnson K, Gerada C, Greenough A. 2003. Substance misuse during pregnancy. *The British Journal of Psychiatry* 183:187-189.

Jones MM, Brugha RF. 1997. Using perinatal audit to promote change. *Health Policy and Planning.*12(3): 183-192.

Kalimba EM, Ballot DE. 2013. Survival of extremely low-birth-weight infants. *South African Journal of Child Health* 7(1): 13-16. DOI:10,7196/SAJCH.488

Katz J, Lee ACC, Kozuki N, Cousens S, Blencowe H, Ezzati M, Bhutta ZA, Marchant T, Willey BA, Adair L, Barros F, Baqui AH *et al.* 2013. Mortality risk in preterm and small-for-gestational-age infants in low-income and middle-income countries: a pooled country analysis. *Lancet* 382:417-425.

Kerber KJ, Lawn JE, Johnson LF, Mahy M, Dorrington RE, Phillips HE, Bradshaw D, Nannan N *et al.*. 2013. South African child deaths 1990-2011: have HIV services reversed the trend enough to meet Millenium Development Goal 4? *AIDS* 27: 2637-2648.

Kinney MV, Kerber KJ, Black RE, Cohen B, Nkrumah F, Coovadia H, Nampala PM, Lawn JE. 2010. Sub-Saharan Africa's Mothers, Newborns, and Children: Where and Why Do They Die? *PLoS Medicine.* 7(6): e1000294. Available online at https://journals.plos.org/plosmedicine/article/file?id=10.1371/journal.pmed.1000294&type=printable (accessed 12 April 2019)

Kirsten GF, Kirsten CL, Henning PA. 2012. The outcome of ELBW infants treated with NCPAP and InSurE in a resource-limited institution. *Pediatrics* 129(4):e952-959.

Klier CM, Grylli C, Amon S, Fiala C, Weizmann-Henelius G, Pruitt SL, Putkonen H. 2012. Is the introduction of anonymous delivery associated with a reduction of high neonaticide rates in Austria? A retrospective study. *BJOG International Journal of Obstetrics and Gynaecology*. 428-434.

Laopaiboon M, Lumbigganon P, Intarut N. 2014. WHO Multi-country Survey of Maternal Newborn Health Research Network. Advanced maternal age and pregnancy outcomes: a multi-country assessment. *BJOG* 2014; 121(suppl 1):49-56. Available online at https://obgyn.onlinelibrary.wiley.com/doi/pdf/10.1111/1471-0528.12659 (Accessed September 2019)

Lawn JE, Kinney MV, Black RE, Pitt C, Cousens S, Kerber K, Corbett E, Moran AC *et al.*. 2012. Newborn survival: a multi country analysis of a decade of change. *Health Policy and Planning.*27: iii6-iii28

Lawn JE, Blencowe H, Oza S, You D, Lee ACC, Waiswa P, Lalli M, Bhutta *et al.*. 2014. Every Newborn 2: Progress, priorities, and potential beyond survival. *Lancet: Every Newborn Study Group.*384:189-205

Lawn JE, Cousens S, Zupan J. 2005. 4 million neonatal deaths: when? where? why? *Lancet*, 365(9462)**:**891-900.

Liu L, Johnson HL, Cousens S, Perin J, Scott S, Lawn JE, Rudan I, Campbell H, Cibulkis R, Reference Group of WHO and UNICEF. 2012. Global, regional and national causes of childhood mortality: an updated systematic analysis for 2010 with time trends since 2000. *The Lancet.* 379: 2151-2161.

Liu L, Oza S, Hogan D, Chu Y, Perin J, Zhu J, Lawn JE, Cousens S, Mathers C, Black RE. 2016a. Global, regional, and national causes of under-5 mortality in 2000-15: an updated systematic analysis with implications for the Sustainable Development Goals. *Lancet*,**388**: 3027-3035.

Liu L, Kalter HD, Chu Y, Kazmi N, Koffi AK, Amouzou A, Joos O, Munos M, Black RE. 2016b. Understanding Misclassification between Neonatal Deaths and Stillbirths: Empirical Evidence from Malawi. *PLoS One*, 11(12):e0168743 doi:10.1371/journal.pone.0168743.

Malherbe HL, Aldous C, Woods D, Christianson A. 2016. The contribution of congenital disorders to child mortality in South Africa. *South African Health Review.*

Mason E, McDougall L, Lawn JE, Gupta A, Claeson M, pillay Y, Presem C, Lukong MB *et al.*. 2014. Every Newborn 5: From evidence to action to deliver a healthy start for the next generation. *Lancet Series Every Newborn Study Group.*

Mathews S, Martin LJ, Coetzee D, Scott C, Naidoo T, Brijmohun Y, Quarrie K. 2016a. The South African child death review pilot: A multiagency approach to strengthen healthcare and protection for children. *SAMJ.* 106(9): 895-899. DOI:10.7196/SAMJ.2016.v106i9.11234.

Mathews S, Martin LJ, Coetzee D, Scott C, Naidoo T, Brijmohun Y. 2016b. Child Deaths in South Africa: Lessons from the child death review pilot: Editorial. *SAMJ* 106(9): 851-852.

Mayosi BM, Lawn JE, Van Niekerk A, Bradshaw D, Abdool Karim SS, Coovadia. 2012. Health in South Africa: changes and challenges since 2009. *www.thelancet.com.* Available online at http://dx.doi.org/10.1016/s0140-6736(12)61814-5). (Accessed May 2019)

Medical Research Council Unit for Maternal and Infant Health Care Strategies. 2001. Saving Babies: Second Perinatal care Survey for South Africa (2000). Pretoria, University of Pretoria.

Medical Research Council Unit for Maternal and Infant Health Care Strategies. 2009. Saving Babies: Sixth Perinatal Care Survey for South Africa (2007 - 2008). Pretoria, University of Pretoria.

Mills S. 2011. Maternal Death Audit as a tool for decreasing maternal mortality. *HNP notes. World Bank.* Available online at http://siteresources.worldbank.org/INTPRH/Resources/376374-1278599377733/MaternalDeathAuditMarch22011.pdf .Accessed September 2015

National Committee for the Confidential Enquiry into Maternal Deaths. 2012. Saving Mothers 2008-2010. Fifth Report on the Confidential Enquiries into Maternal Deaths in South Africa.

National Perinatal Morbidity and Mortality Committee (NaPeMMCo). 2011. National Perinatal Morbidity and Mortality Committee Report 2008-2010. Executive summary. Available online at https://policyresearch.limpopo.gov.za/bitstream/handle/123456789/891/National%20Perinatal%20Morbidity%20and%20Mortality%20Committee%20Report. Accessed June 2018.

National Perinatal Morbidity and Mortality Committee (NaPeMMCo). 2017. Saving Babies: Third Triennial Report of the National Perinatal Morbidity and Mortality Committee (2014-2016).

National Department of Health, Statistics South Africa (Stats SA), ICE. 2017. South African Demographic and Health Survey 2016: Key Indicators. Pretoria: Stats SA available online at http://www.statssa.gov.za/publications/Report%2003 Accessed January 2019.

Ndiaye K, Portillo E, Ouedraogo D, Mobley A, Babalola S. 2018. High risk advanced Maternal age and High Parrity pregnancy: Tackling a neglected need through Formative Research and Action. *Global Health Science Practice* 6(2):370-380.

Norheim OF, Jha P, Admasu K, Godal T, Hum RJ, Kruk MF, Gomez-Dantes O, Mathers C *et al.* .2015. Avoiding 40% of the premature deaths in each country, 2010-30:review of national mortality trends to help quantify the UN Sustainable Development Goal for health. *Lancet.* 385: 239-251

Noubiap JJ, Bigna JJ, Nyaga UF, Jingi AM, Kaze AD, Nansseu JR, Domgue JF. 2019. The burden of hypertensive disorders of pregnancy in Africa: A systematic review and meta-analysis. *Journal of Clinical Hypertension* 21(4):479-488. https://doi.org/10.1111/jch.13514 (Accessed January 2020)

Oestergaard MZ, Inoue M, Yoshida S, Mahanani WR, Gore FM, Cousens S, Lawn JE, Mathers CD, on behalf of the United Nations Inter-agency Group for Child Mortality Estimation and the Child Health Epidemiology Reference Group. 2011. Neonatal Mortality Levels for 193 Countries with trends since 1990: A Systematic Analysis of Progress, Projections, and Priorities. *PLoS Medicine*. 8(8): 1-12.

Outwater A, Mgaya E, Campbell JC, Becker S, Kinabo L, Mbassa Menick D. 2010. Homicide of children in Dar es Salaam, Tanzania, 2005. *East Afr J Public Health.* 7(4): 345-349.

Oza S, Lawn JE, Hogan DR, Mathers C, Cousens SN. 2015. Neonatal cause-of-death estimates for the early and late neonatal periods for 194 countries:2000-2013. *Bull WORLD Health Organ* 93:19-28

Pattinson R, Rhoda N. 2014. Saving Babies 2012-2013: Ninth report on Perinatal care in South Africa. Pretoria: Tshepa Press.

Philpott H, Voce A. 2001. Four Key Components of an effective Perinatal Audit process. *Health Systems Trust.* Available online at http//:hst.org.za. accessed September 2015

Petersen Williams P, Jordaan E, Mathews C, Lombard C, Parry CDH. 2014. Alcohol and other drug use during pregnancy among women attending MOUs in the Cape Metropole, SA. *Advances in Preventative Medicine.* Available online at https://www.doi.org/10.1155/2014/871427 (Accessed December 2019)

Prinsloo M, Laubscher R, Neethling I, Bradshaw D. 2011. Fatal violence among children under 15 years in four cities of South Africa, 2001-2005. Int J Inj Contr Saf Promot. 19:181-184. Doi 10 1080/17457300.2011.635211 PMID 22166056.

Quarrie KC, Burger E. 2018. Correlation of postmortem lodox digital radiological images with histopathological findings at autopsy: A prospective autopsy study at the Tygerberg Forensic Pathology Service Facility. For the purpose of a Master of Medicine (Forensic Pathology) at Stellenbosch University.

Regmi PR, Van Teijlingen E, Hundley V, Simkhada P, Sharma S, Mahato P. 2016. Sustainable development Goals: relevance to maternal and child health in Nepal. *Health Prospect: Journal of Public Health.* 15(1): 9-10.

Reid AE, Hendricks MK, Groenewald P, Bradshaw D. 2016. Where do children die and what are the causes? Under-5 deaths in the Metro West geographical service area of the Western Cape, South Africa, 2011. *SAMJ.* 106(4): 359-364.

Rhoda NR, Greenfield D, Muller M, Prinsloo R, Pattinson B, Kauchali S, Kerber K. 2014. Experiences with perinatal death reviews in South Africa- the Perinatal Problem Identification Programme: scaling up from programme to province to country. *BJOG.* 121(suppl 40: 160-166.

Rhoda NR, Velaphi S, Gebhardt GS, Kauchali S, Barron P. 2018. Reducing neonatal deaths in South Africa: Progress and challenges. *SAMJ.*108(Suppl 1): 1-7. DOI:10.7196/SAMJ.2018v108i3.128804.

Riemer LJ, Le Roux SM, Harrison MC, Tooke L. 2019. Short term outcomes of HIV-exposed and HIV-unexposed preterm, very low birthweight neonates: a longitudinal, hospital-based study. *Journal of Perinatology.* Available online at https://doi.org/10.1038/s41372-019-0541-4 (Accessed January 2020)

Shisana O, Rehle T, Simbayi LC, Zuma K, Jooste S, Zungu N, Labadarios D, Onoya D. 2014. South African National HIV Prevalence, Incidence and Behaviour Survey, 2012. Cape Town: HSRC Press

Simonsen KA, Anderson-Berry AL, Delair SF, Dele Davies H. 2014. Early-onset Neonatal Sepsis. *Clin Microbiol Rev* 27(1):21-47. Doi 10.1128/CMR.00031-13.

Singh NS, Huicho L, Afnan-Holmes H, John T, Moran AC, Colboum T, Grundy C, Matthews M. 2016. Countdown to 2015 country case studies. Systemic tools to address the 'black box" of health systems and policy assessment. *BMC Public Health.* doi: 10.1186/s12889-016-3402-5

Slogrove AL, Goetghebuer T, Cotton M, Singer J, Bettinger J. 2016. Pattern of Infectious Morbidity in HIV-Exposed Uninfected Infants and Children. *Frontiers in Immunology*. 7(164): 1-10. DOI.10.3389/immu.2016.00164.

Souza RT, Cecatti JG, Passini R, Jr, Tedesco RP, Lajos GJ, Nomura ML. 2016. The Burden of Provider-Initiated Preterm Birth and Associated Factors: Evidence from the Brazilian Multicentre Study on Preterm Birth (EMIP). *PLoS ONE* 11(2):e0148244.doi:10.1371/journal.pone.0148244

Statistics South Africa. 2011. Census 2011. Statistics South Africa. Pretoria. Available online https://www.statssa.gov.za (Accessed January 2019)

Statistics South Africa. 2015. Millenium Development Goals 4: Reduce Child Mortality. Statistics South Africa. Pretoria.

Stein DJ, Seedat S, Herman AA. 2007. Findings from the First South African Stress and Health Study, Policy brief. South African Medical Research Council, Cape Town, South Africa.

Stratton KR, Howe CJ, Battaglia C. 1996. Fetal Alcohol Syndrome Diagnosis, Epidemiology, Prevention and Treatment. *National Academy Press*.Washington, DC, USA.

Tanaka CT, Berger W, Valenca AM, Coutinho ESF, Jean-Louis G,Fontanelle LF, Mendlowicz MV. 2017. The worldwide incidence of neonaticide: a systematic review. *Arch Women's Mental Health.* 20:249-256. DOI 10.1007/s00737-016-0703-8.

Thadeus S, Maine D. 1994. Too far to walk: maternal mortality in context. *Social Science and Medicine.* 30(8): 1091-1110.

Tibrewala NS, Tibrewala SN, Tibrewala VN. 1980. Epidemiology and prevention of low birth weight babies in a developing country. *Bull in Pediatr Assoc*. 3(5):27-36.

United Nations. 2015a. Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development. Global targets for the 2030 Agenda. Available online at https://unstats.un.org/sdgs/indicators/Global%20Indicator%20Framework%20after%20refinement_Eng.pdf. (Accessed January 2019).

United Nations. 2015b. Global Strategy for Women's, Children's and Adolescents' Health: 2016-2013. New York. Every Woman, Every Child. Available online at https://www.who.int/life-course/partners/global-strategy/globalstrategyreport2016-2030-lowres.pdf. (Accessed March 2019).

United Nations Inter-Agency Group for Child Mortality Estimation. Levels and Trends in Child Mortality: Report 2017. Available online at https://www.unicef.org/publications/files/Child_Mortality_Report_2017.pdf (Accessed April 2019)

Upadhyay RP, Rai SK, Krishnan A. 2012. Using Three Delays Model to Understand the Social Factors Responsible for Neonatal Deaths in Rural Haryana, India. *Journal of Tropical Paediatrics.*59(2): 100-105.

Van Niekerk AM, Cullis RM, Linley LL, Zuhlke L. 2016. Feasibility of Pulse Oximetry Pre-discharge Screening Implementation for detecting Critical Congenital heart lesions in newborns in a secondary-level maternity hospital in the Western Cape, South Africa: The POPSICLe study. *SAMJ* 106(9):817-821.

Villar J, Ba'aqeel H, Piaggio G. 2001. WHO Antenatal Care Trial Research Group. WHO antenatal care randomised trial for the evaluation of a new model of routine antenatal care. Lancet 2001;357(9268):15511564. Available online at [http://dx.doi.org/10.1016/S0140-6736(00)04722-X]

Velaphi S, Rhoda N. 2012. Reducing neonatal deaths in South Africa- are we there yet, and what can be done? *South African Journal of Child Health.*6(3): 67-71.

Waiswa P, Kallander K, Peterson S, Tomson G, Pariyo GW. 2010. Using the three delays model to understand why newborn babies die in eastern Uganda. *Tropical Medicine and International Health.* 15(8): 964-972.

Watcham SJ, Schon S, Christianson. 2007. Neglect of care of pregnant South African women of advanced maternal age. *S Afr med J* 97(11): 1064, 1068-1069.

Western Cape Department of Health, South Africa. 2014. Healthcare 2030: The road to wellness. Department of Health. Cape Town. Available online at https://www.westerncape.gov.za/assets/departments/health/healthcare2030.pdf. (Accessed April 2019)

Western Cape Department of Health, South Africa. 2017. Caring management at the margins of viability. Circular H10 2017.

Woldesenbet SA, Kufa T, Lombard C, Manda S, Ayalew K, Cheyip M, Puren A. 2019. The 2017 National Antenatal Sentinel HIV Survey, South Africa, National Department of Health.

World Health Organisation. 2010. International Statistical Classification of Diseases and Related Health Problems: Volume 2 Instruction Manual. Geneva.

World Health Organisation. 2014. Every Newborn: An Action Plan to End Preventable Deaths. *World Health Organisation. WHO Library Cataloguing-in-Publication Data.* Geneva. Available on https://apps.who.int/iris/bitstream/handle/10665/127938/9789241507448-eng.pdf (Accessed 8 April 2019)

World Health Organisation. 2015. Guideline: Managing possible serious bacterial infection in young infants when referral is not feasible.

World Health Organisation.2016. Decreasing deaths during pregnancy in South Africa by improving antenatal care. Available online https://www.who.int/reproductivehealth/news/antenatal-care-south-africa/en/
Accessed October 2019)

Yves J, Vermeulen K, Vellinga S. 2006. A Systematic Review of Grand Multiparity. *Current Womens Health Review.* 2(1): 25-32. Available online at

https://www.researchgate.net/publication/244932251_A_Systematic_Review_of_Grand_Multiparity (Accessed September 2019).

Appendices

Appendix 1: Table of the variables used in the study

Neonatal Identification number	Birth unit	Age at death (days)	Birthweight (grams)	Obstetric cause of Death	Final cause of death	Avoidable/Modifiable factor	Data source

Appendix 2: Obstetric cause of perinatal death (PPIP version 3)

0100 **SPONTANEOUS PRETERM LABOUR**
0101 Ideopathic preterm labour
0102 Preterm premature rupture of membranes
0103 Preterm premature rupture of membranes with chorioamnionitis
0104 Preterm labour with chorioamnionitis with intact membranes
0105 Cervical incompetence
0106 Iatrogenic preterm delivery for no real reason
0200 INFECTIONS
0201 Syphilis
0202 Amniotic fluid infection
0203 Beta-haemolytic streptococcal infection
0204 Malaria
0298 AIDS/HIV related *** NOT USED ***
0299 Other infections
0300 ANTEPARTUM HAEMORRHAGE
0301 Abruptio placentae
0302 Abruptio placentae with hypertension
0303 Placenta praevia
0304 Antepartum haemorrhage of unknown origin
0400 INTRAUTERINE GROWTH RETARDATION
0401 Idiopathic intrauterine growth retardation
0402 IUGR with histological features of ischaemic placental disease
0403 Postmaturity
0500 HYPERTENSIVE DISORDERS
0501 Chronic hypertension
0502 Proteinuric hypertension
0503 Eclampsia

0504 Pregnancy-induced hypertension without proteinuria
0600 FETAL ABNORMALITY
0601 Fetal chromosomal abnormality
0602 Neural tube defects
0603 Cardiovascular system abnormality
0604 Renal system abnormality
0605 Hydrocephalus
0606 Abnormality of multiple systems
0607 Non-immune hydrops fetalis
0608 Non-specific fetal abnormality - FLK
0700 TRAUMA
0701 Motor vehicle accident
0702 Accidental abdominal trauma
0703 Domestic violence
0704 Assault
0800 INTRAPARTUM ASPHYXIA
0801 Labour related intrapartum asphyxia
0802 Meconium aspiration
0803 Cord prolapse
0804 Cord around the neck
0805 Traumatic breech delivery
0806 Traumatic assisted delivery
0807 Shoulder dystocia
0808 Precipitous labour
0809 Ruptured uterus
0900 MATERNAL DISEASE
0901 Maternal diabetes mellitus
0902 Maternal heart disease
0903 Maternal disease due to herbal medicine use
0999 Other maternal disease
1000 MISCELLANEOUS
1001 Rhesus isoimmunisation
1002 Twin-to-twin transfusion
1003 Extra-uterine pregnancy
1099 Other cause of death not described in classification
1100 INTRAUTERINE DEATH
1101 Unexplained intrauterine death - fresh
1102 Unexplained intrauterine death - macerated
1103 Unexplained IUD due to lack of notes
1200 NO OBSTETRIC CAUSE / NOT APPLICABLE
1201 No obstetric cause / Not applicable

Appendix 3: Final cause of neonatal death (PPIP version 3)

0100 IMMATURITY RELATED
0101 Extreme multi-organ immaturity
0102 Hyaline membrane disease
0103 Necrotizing enterocolitis
0104 Pulmonary haemorrhage
0105 Intraventricular haemorrhage
0199 Other immaturity related causes
0200 HYPOXIA
0201 Hypoxic ischaemic encephalopathy
0202 Meconium aspiration
0203 Persistent fetal circulation
0299 Other complications of hypoxia
0300 INFECTION
0301 Septicaemia
0302 Pneumonia
0303 Congenital syphilis
0304 HIV infection
0305 Congenital infection
0306 Group B streptococcal infection
0307 Meningitis
0308 Nosocomial infection
0309 Tetanus

0399 Other infection
0400 CONGENITAL ABNORMALITIES
0401 Central nervous system abnormalities
0402 Cardiovascular system abnormalities
0403 Renal system abnormalities
0404 Alimentary tract abnormalities (excl. diaphragmatic hernia)
0405 Chromosomal abnormality
0406 Biochemical abnormality
0407 Respiratory abnormalities (incl. diaphragmatic hernia)
0499 Other congenital abnormalities (incl. multiple & skeletal)
0500 TRAUMA
0501 Subaponeurotic haemorrhage
0599 Other trauma
0600 MISCELLANEOUS
0601 Isoimmunisation
0602 Non-immune hydrops
0603 Sudden Infant Death Syndrome (SIDS)
0604 Apnoeic attacks in the first week
0605 Haemorrhagic disease of the new-born
0606 Aspiration pneumonia
0607 Hypovolaemic shock
0608 Hypothermia
0609 Hypoglycaemia
0699 Other cause of death not described in classification
0700 UNKNOWN CAUSE OF DEATH
0701 Unknown cause of death
0900 INTRAUTERINE DEATH
0901 Intrauterine death

Appendix 4: Final cause of child death (Child PIP version 3.1)

Infections and Parasitic Diseases

Acute diarrhoea, hypovolaemic shock 101

Chronic diarrhoea 102

Dysentery 103
TB: Pulmonary 110
TB: Meningitis 111
TB: Miliary, other extra-pulmonary 112
Septicaemia, possible serious bacterial infection 120
Congenital Infections (not HIV) 130
Meningitis: Bacterial 140
Meningitis: Viral (meningo-encephalitis) 141
Other inflammatory disease of CNS (e.g. abscess) 142
Measles 150
Other possible serious infection (specify) 151
Malaria 170
Hospital-acquired infection 180
Oncology, Haematology
Leukaemias 201
Tumours 204
Anaemia 202
Other Oncology/Haematology (specify) 203
Endocrine, Nutritional, Metabolic
IDDM, DKA 301
Hypoglycaemia 304
Other Endocrine, Nutritional, Metabolic (specify) 305
Nervous System
Status epilepticus 401
Other Nervous System (specify) 402
Circulatory System
RHD, Rheumatic fever 501
Heart failure, Pulmonary oedema 502
Myocarditis 503

Cardiomyopathy 504
Congenital Heart Disease 507
Endocarditis 505
Other Circulatory System (specify) 506
Respiratory System
Croup 601
Pneumonia, ARI 602
PCP (suspected) 603
PCP (confirmed) 608
Pneumothorax, Pyothorax, Pleural effusion 604
Asthma 605
Congenital malformations of the respiratory system 606
Other Respiratory System (specify) 607
Digestive System
Cirrhosis, Portal Hypertension, Liver Failure, Hepatitis 701
Surgical (appendix, hernia, intestines, peritoneum) 702
Other Digestive System (specify) 703
Genito-urinary System
Acute nephritis 801
Acute renal failure 802
Chronic renal disease 803
Other Genito-urinary System (specify) 804
Ill-defined/Unknown Cause Ill-defined/Unknown causes of mortality 900
Other Diagnosis Other diagnosis (specify) 901
Burns Burns 1000
Poisoning
Paraffin 1101
Corrosives 1102
Other Poisoning (specify) 1103
Bites and Stings, Toxic plants Bites and stings, Toxic plants 1200
Inhalation/Aspiration Inhalation of foreign body or gastric contents 1300
Accidents
Transport-related accidents 1400
Other accidents (incl. Drowning; specify) 1500
Non-accidental injury, Abuse Non-accidental injury, Abuse-related, Neglect 1600
Homicide Homicide 1700
Suicide Suicide 1800

Underlying Conditions Code

Cerebral palsy 1
Hydrocephalus 2
Birth defect (preconception = chromosomal/genetic, or post conception e.g. foetal alcohol syndrome) 3
Ex-low birth weight/preterm infant 4
Twin/Multiple pregnancy 5
Other Underlying Condition (specify) 10

Appendix 5: Avoidable factors (PPIP version 3)

0100 PATIENT ASSOCIATED

0101 Never initiated antenatal care

0102 Booked late in pregnancy
0103 Infrequent visits to antenatal clinic
0104 Failed to return on the prescribed date
0105 Inappropriate response to rupture of membranes
0106 Inappropriate response to antepartum haemorrhage
0107 Inappropriate response to poor fetal movements
0108 Delay in seeking medical attention during labour
0109 Delay in seeking help when baby ill
0110 Declines admission/treatment for personal/social reasons
0111 Partner/Family declines admission/treatment
0112 Alcohol abuse
0113 Smoking
0114 Illegal drug use
0115 Assault

0116 Attempted termination of pregnancy
0117 Infanticide
0118 Abandoned baby
0199 Other patient associated factors
0200 ADMINISTRATIVE PROBLEMS
0201 Lack of transport - Home to institution
0202 Lack of transport - Institution to institution
0203 Lack of adequate neonatal transport
0204 No syphilis screening performed at hospital / clinic
0205 Result of syphilis screening not returned to hospital/clinic
0206 No on-site syphilis testing available
0207 No Motherhood card issued
0208 No dedicated high risk clinic at referral hospital
0209 Inadequate facilities/equipment in neonatal unit/nursery
0210 Inadequate theatre facilities
0211 No accessible neonatal ICU bed with ventilator
0212 Inadequate resuscitation equipment
0213 Insufficient blood / blood products available
0214 Insufficient nurses on duty to manage the patient adequately
0215 Insufficient doctors available to manage the patient
0216 Personnel not sufficiently trained to manage the patient
0217 Personnel too junior to manage the patient
0218 Staff rotation too rapid
0219 Anaesthetic delay
0220 Theatre delay: staff not available
0221 Theatre delay: all theatres occupied
0222 Congenital abnormality not diagnosed: No ultrasound service available
0299 Other administrative problems
0300 MEDICAL PERSONNEL ASSOCIATED
0301 No response to history of stillbirths, abruptio etc.
0302 No response to maternal glycosuria
0303 No response to poor uterine fundal growth
0304 No response to maternal hypertension
0305 No response to positive syphilis serology test
0306 No response to apparent postterm pregnancy
0307 No response to history of poor fetal movement
0308 No antenatal response to abnormal fetal lie
0309 Multiple pregnancy not diagnosed antenatally
0310 Physical examination of patient at clinic incomplete
0311 GP did not give card/letter about antenatal care
0312 Medical personnel overestimated fetal size
0313 Medical personnel underestimated fetal size
0314 Fetal distress not detected antepartum; fetus monitored
0315 Fetal distress not detected antepartum; fetus not monitored
0316 Antenatal steroids not given
0317 Poor progress in labour, but partogram not used
0318 Poor progress in labour, but partogram not used correctly
0319 Poor progress in labour - partogram interpreted incorrectly
0320 Fetal distress not detected intrapartum; fetus monitored
0321 Fetal distress not detected intrapartum; fetus not monitored
0322 Breech presentation not diagnosed until late in labour
0323 Multiple pregnancy not diagnosed intrapartum
0324 Incorrect management of hypertensive disease
0325 Incorrect management of antepartum haemorrhage
0326 Incorrect management of premature labour
0327 Incorrect management of cord prolapse
0328 Iatrogenic delivery for no real reason
0329 Management of 2nd stage: prolonged with no intervention
0330 Management of 2nd stage: inappropriate use of forceps
0331 Management of 2nd stage: inappropriate use of vacuum
0332 Neonatal resuscitation inadequate
0333 Neonatal care: inadequate monitoring
0334 Neonatal care: management plan inadequate
0335 Baby managed incorrectly at Hospital/Clinic
0336 Baby sent home inappropriately
0337 Delay in doctor responding to call
0338 Doctor did not respond to call

0339 Delay in medical personnel calling for expert assistance
0340 Delay in referring patient for secondary/tertiary treatment
0341 Nosocomial infection
0342 Inadequate / No advice given to mother
0343 Congenital abnormality not diagnosed; U/S examination not performed
0344 Congenital abnormality not diagnosed; U/S examination was performed
0399 Other medical personnel associated factors
0400 INSUFFICIENT NOTES TO COMMENT ON AVOIDABLE FACTORS
0401 Insufficient notes
0402 File missing
0403 Antenatal card lost