Preventable Feto-infant Mortality

Application of a Conceptual Framework for Perinatal Health Surveillance to Manitoba Perinatal Outcomes

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ABSTRACT

Background: Perinatal health surveillance systems have lacked conceptual frameworks to translate data into information for policy and program planning. This paper demonstrates the application of a conceptual framework in the analysis of feto-infant mortality data in the province of Manitoba.

Methods: Fetal and infant deaths were categorized according to a two-dimensional framework of birthweight and age-at-death, and grouped into four broad categories of contributors to perinatal health: Maternal Health, Maternal Care, Newborn Care, and Infant Care. Birth Weight Proportionate Mortality Rates (BWPMR) were calculated for each of the four categories, and preventable "excess" feto-infant mortality was estimated through comparisons to a benchmark sub-population.

Results: Between 1985 and 1998, feto-infant mortality declined from 12.3 to 9.8 deaths per 1000 births in Manitoba. Much of this decline occurred in the Newborn Care category; there were only slight declines in deaths attributed to Maternal Health and Infant Care factors. Comparison of the feto-infant mortality rate to the benchmark rate revealed an excess of 3.46 deaths per 1000 births, an "opportunity gap" of 33%. Substantial regional variations in feto-infant mortality rates were observed.

Summary: Application of this conceptual framework provided useful information to aid in policy and program planning. As the greatest excess feto-infant mortality was observed in the Maternal Health and Infant Care categories, attention to the broader determinants of health which influence these categories will be required.

La traduction du résumé se trouve à la fin de l'article.

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Public health surveillance has been defined as the ongoing systematic collection, analysis, and interpretation of outcome-specific health data for use in the planning, implementation, and evaluation of public health practice.¹ Dr. Brian McCarthy of the Centers for Disease Control and Prevention (CDC), Atlanta, has defined perinatal health surveillance as a dynamic process which collects, analyzes, and responds to data on the occurrence and distribution of maternal and child health events in a defined population.² Common to both of these definitions of surveillance are analysis and interpretation to turn raw data into useful "information". This information can be used for a variety of purposes, including: estimating the burden of ill health and poor outcomes, generating hypotheses as to the contributors to poor outcomes, setting research priorities, planning and evaluating preventive and treatment services, and monitoring trends in outcomes and practices over time.

Perinatal databases and information systems have heretofore lacked conceptual frameworks on which to base such analyses and assist in the translation of data into information useful for health policy-making. This paper demonstrates the application of a conceptual framework to perinatal surveillance data in the Canadian province of Manitoba, thereby providing useful information on perinatal outcomes and the potential for improving these outcomes. The particular outcome of focus in this paper is the *feto-infant mortality rate*, which includes fetal mortality after 28 weeks of gestation and infant mortality during the first year of life. Feto-infant mortality has been previously used as an indicator of overall maternal/infant well-being in populations, and has been observed to decrease dramatically over the last century in most countries.³⁻⁵

The perinatal health surveillance conceptual framework used in this study was developed by Dr. Brian McCarthy and colleagues at the World Health Organization (WHO) Collaborating Center in Perinatal Care, Centers for Disease Control and Prevention, Atlanta, Georgia.^{2,6-8} The conceptual framework analyzes feto-infant mortality by birthweight and age-at-death (Figure 1), and is used to determine the strategies having the greatest potential for reducing preventable

Birthweight (grams)	Age at Death			
	Late Fetal (28+ weeks)	Early Neonatal (0-7 days)	Late Neonatal 8-28 days)	Post-neonatal (29-364 days)
<1000				
1000-1499		MATERNAL HEALTH		
1500-2499		NEWBORN CARE		
2500+	MATERNAL CARE			INFANT CARE

Figure 1. Framework for classifying feto-infant mortality by weight and age at death

feto-infant mortality through assessment of factors in four major categories: Maternal Health, Maternal Care, Newborn Care, and Infant Care.² Although these categories are not seen as mutually exclusive, this classification scheme attributes late fetal deaths (deaths occurring at 28 weeks gestation or greater) and infant deaths of very low birthweight (<1500 grams) to Maternal Health factors. Among intermediate (1500-2499 grams) and normal (2500+ grams) birthweight groupings, late fetal deaths are attributed to Maternal Care factors. Deaths of normal birthweight (>2499 grams) infants in the early neonatal period and intermediate weight infants (1500-2499 grams) in the early or late neonatal periods are attributed to Newborn Care factors. Finally, deaths after 1 week of life in normal birthweight infants and after 4 weeks of life in intermediate weight infants are attributed to Infant Care factors.

The Maternal Health category includes factors affecting adequate growth and development of the fetus, and is influenced by the broader determinants of health such as income and social status, education, physical environment, health services, and culture and ethnicity.⁹⁻¹¹ Maternal Health is also affected by factors such as maternal age and parity, pregnancy spacing, nutri-

tional status, stress, smoking, drug and alcohol use, chronic health conditions, and access to primary health care. Very low birthweight (VLBW) deaths can best be prevented by addressing Maternal Health issues.¹² The Maternal Care category includes the availability of high quality care during pregnancy and in the labour and delivery period. Maternal Care is affected by access to prenatal care and screening; availability of high-risk pregnancy follow-up; an assessment, referral, and transfer system for maternal/fetal complications; intrapartum fetal health surveillance; and surgical services to perform emergency caesarean births. The Newborn Care category includes factors that exert a strong influence on infant health in the neonatal period, including a regional referral and neonatal transport system, timely and skilled resuscitation, attention to thermoregulation, and access to neonatal intensive care. In the category Infant Care are factors that influence the health of infants after the neonatal period, including immunizations, breast feeding promotion and support, community services, injury prevention and control, and high risk infant follow-up. Socioeconomic variables such as family income and maternal education, and maternal race or ethnicity, also influence infant health and infant mortality

rates.^{9,13-15} Analysis of feto-infant mortality according to these four categories in the framework provides an innovative method of monitoring and investigating preventable feto-infant mortality problems, targeting further investigations and informing policy and program activities.¹²

METHODS

Study setting

This study was conducted in the province of Manitoba. Manitoba has a population of 1.14 million (1997). Over 60% of the residents live in the only major urban centre, Winnipeg (population 647,000). The remainder of the population is distributed among small regional centres and farming communities in the rural southern half of the province and mining, forestry and Aboriginal communities in the northern half of the province. Each year in Manitoba there are approximately 21,000 pregnancies that result in a hospital-based outcome, about 75% of which result in a live birth; about 110 pregnancies result in stillbirth each year, and the remainder result in spontaneous or therapeutic abortions.^{16,17}

Data sources

The main source of data for this study was the Manitoba Health Perinatal Database for the years 1985 through 1998. The provincial health department (Manitoba Health) maintains computerized health records based on health services utilization for all individuals enrolled in the universal health insurance system. For hospitalizations and/or hospital outpatient services, each hospital submits to Manitoba Health a hospital separation abstract that includes the patient's personal health identification number, dates of admissions and discharge, up to 16 ICD-9-CM diagnoses codes, and up to 12 ICD-9-CM procedure codes. The information gathered from the hospital separation abstracts is entered into a hospital abstract database. The utility, accuracy and completeness of these databases have been documented.¹⁸ Using the hospital abstract database, records of women who have had a pregnancy that resulted in a hospital-based birth and their infants were identified and linked in a distinct Perinatal Database, maintained by the Manitoba Health Epidemiology Unit. This confiden-

Figure 2. Time trends in Manitoba fetoinfant mortality per 1000 births

Figure 3. Manitoba regional fetoinfant mortality per 1000 births, 1989-1998

tial, linked obstetrical-newborn database captures live births as well as stillbirths. It has a hospital discharge abstract record for each hospital-based delivery in Manitoba since 1984.

Application of conceptual framework and analysis

The perinatal health surveillance conceptual framework was applied to fetal death and linked birth and infant death files in Manitoba, as follows. The first step involved tabulating fetoinfant mortality rates (per 1000 total births) in a two-dimensional matrix of birthweight and age-at-death, resulting in a 16 cell table (Figure 1). The 16-cells were then grouped into the 4 broad categories of contributors to perinatal health discussed above: Maternal Health, Maternal Care, Newborn Care, and Infant Care (Figure 1).

Birth Weight Proportionate Mortality Rates (BWPMR) were then calculated for each of the four categories. The BWPMR is the number of fetoinfant deaths in a given weight group divided by the total

number of fetal deaths and live births for all weight groups. The proportionate mortality for the four categories was then added together to derive the overall fetoinfant mortality rate. The four categories were compared to determine where higher fetoinfant mortality rates occur. The fetoinfant mortality rates also were used to compare rates over time and across different population groups, defined by several variables (maternal age, area of residence, median household income of postal area of residence). Comparisons between within-province regional rates were made at two levels. The first involved subdividing the province into three large regions with common demographic characteristics: North Rural (consisting of the Burntwood, Churchill, Nor-Man and North Eastman Regional Health Authorities [RHAs]), South Rural (consisting of all the remaining rural RHAs) and Winnipeg (the only entirely urban RHA). The second level of regional comparisons was at the level of Manitoba's 12 RHAs (refer to Figure 1 in Brownell et al., this issue¹⁹).

Figure 4. Fetoinfant mortality by age and median household income, 1989-1998

The next analysis step involved calculation of excess (preventable) fetoinfant mortality rates for the period 1989 to 1998. Excess fetoinfant mortality is calculated by subtracting the mortality rates in a benchmark population from the rates in the comparison population. We chose as a benchmark population women aged 20-34 years of age who live in Winnipeg residential areas with a high median household income (greater than \$43,457). The difference between a region's mortality rate and the benchmark rate may be viewed as an "opportunity gap" that reveals the potential for reduction in fetoinfant mortality in that region.

RESULTS

Overall and category-specific fetoinfant mortality rates for Manitoba are summarized in Figure 2. Between 1985-87 and 1997-98, there was a 20% reduction in overall fetoinfant mortality in the province of Manitoba (from 12.3 to 9.8 deaths per 1000 births). There were reduc-

TABLE I

Feto-Infant Mortality Rates per 1,000 Births, 1989-1998

	Maternal Health		Maternal Care		Newborn Care		Infant Care		Total Feto-Infant Mortality	
	2.76	Excess	1.88	Excess	1.16	Excess	1.16	Excess	6.96	Excess
Benchmark										
Manitoba	4.02	1.26	2.29	0.41	1.59	0.43	2.52	1.36	10.42	3.46
Winnipeg	3.83	1.07	2.16	0.28	1.21	0.05	2.02	0.86	9.22	2.26
Brandon	3.46	0.70	1.57	-0.31	1.42	0.26	1.57	0.41	8.02	1.06
North Eastman	2.84	0.08	2.08	0.20	1.89	0.73	4.16	3.00	10.97	4.01
South Eastman	4.05	1.29	2.56	0.68	1.62	0.46	1.75	0.59	9.98	3.02
Interlake	3.93	1.17	2.51	0.63	1.42	0.26	2.95	1.79	10.81	3.85
Central	4.30	1.54	2.77	0.89	1.67	0.71	2.43	1.27	11.37	4.41
Marquette	4.34	1.58	1.69	-0.19	1.69	0.53	1.93	0.77	9.65	2.69
South Westman	3.69	0.93	1.97	0.09	1.47	0.31	2.46	1.30	9.59	2.63
Parkland	2.71	-0.05	2.32	0.44	1.93	0.77	3.48	2.32	10.44	3.48
Nor-Man	2.16	-0.60	1.73	-0.15	2.59	1.43	3.03	1.87	9.51	2.55
Burntwood	3.72	0.96	3.64	1.76	1.86	0.70	5.50	4.34	14.72	7.76
Churchill	unstable rates		unstable rates		unstable rates		unstable rates		unstable rates	

tions in the mortality rates in all four categorical areas during this 13-year period. However, much of the decline is attributable to improvement in the Newborn Care category, in which the mortality rate decreased by 35%. By contrast, mortality in the Maternal Health category improved by only 1.4% during this period. In terms of BWPMR, by 1997-98, approximately 43% of the feto-infant mortality (4.26 per 1000) occurred in the very low birthweight (Maternal Health) category, 21% in the Infant Care category (2.10 per 1000), 19% in the Maternal Care category (1.89 per 1000), and 16% in the Newborn Care category (1.57 per 1000).

There were substantial regional variations in feto-infant mortality rates in Manitoba. During the 1989-1998 time period, the highest rates were in the North Rural region of the province (Figure 3), followed by the South Rural region, and finally, Winnipeg. The greatest regional differences in category-specific feto-infant mortality rates were in the Infant Care category where the North Rural region had a 2.3-fold higher mortality rate than the city of Winnipeg (4.62 versus 2.02 per 1000, Figure 3). Feto-infant mortality rates by RHA are summarized in Table I. During the 1989-98 period, the Burntwood RHA (in the North Rural region) had the highest overall feto-infant mortality (14.72 per 1000), approximately 80% higher than the lowest, Brandon RHA (8.02 per 1000). Proportionately, the major contributions to this relatively high total mortality rate in Burntwood came from the Infant Care and Maternal Care categories.

Variations in feto-infant mortality by maternal age and median household income are illustrated in Figure 4 (analysis

restricted to Winnipeg residents). In each age group, women living in areas of the city with a median annual household income greater than \$43,457 (i.e., the upper one third) had lower feto-infant mortality rates than women living in areas with a median household income less than \$35,772 (i.e., the lower one third). Furthermore, within both income strata, women aged 20-34 years had lower feto-infant mortality rates than women aged less than 20 years or greater than 34 years.

"Excess" feto-infant mortality in Manitoba and each of its RHAs in comparison to the "benchmark" rate is summarized in Table I. The overall feto-infant mortality rate in the benchmark population for 1989-1998 was 6.96 per 1000, compared to an overall Manitoba rate of 10.42 per 1000. This implies an "opportunity gap" in perinatal mortality of 3.46 per 1000. In other words, if all of Manitoba were able to achieve the feto-infant mortality rates achieved by the benchmark population, the feto-infant mortality rate would decline by 3.46 per 1000, or 33%. There was excess feto-infant mortality in Manitoba in all four categories, with the greatest excesses in the Infant Care (1.36 per 1000) and the Maternal Health (1.26 per 1000) categories. The opportunity gaps for the Newborn Care and Maternal Care categories were relatively small, at 0.43 and 0.41 per 1000, respectively.

Analysis of within-province regional differences in excess feto-infant mortality (Table I) again illustrated that the Burntwood RHA has the greatest "opportunity gap", followed by the Central, North Eastman and Interlake RHAs. There was some inter-regional variation in terms of which category contributed most

to the excess mortality. In Burntwood, Infant Care (56% of total excess) and Maternal Care (23%) presented the main opportunity gaps, whereas in Central RHA, Maternal Health (35%) and Infant Care (29%) were the greatest categorical contributors. In North Eastman, Infant Care (75% of total excess) was by far the greatest contributor, followed by Newborn Care (18%), with minimal excess mortality in the Maternal Health or Maternal Care categories in this region. In contrast to most of the rural regions, in Winnipeg, the greatest opportunity gap existed in the Maternal Health area (47% of total excess). However, common to all regions except South Eastman was the importance of Infant Care as either the first or second most important contributor to overall excess feto-infant mortality.

DISCUSSION

Using a conceptual framework to guide the interpretation of perinatal health surveillance data helps to focus policy, program and research priorities on the areas of greatest need and potential for improvement. Application of the framework described in this paper involves analyzing feto-infant mortality rates and estimating excess mortality rates to identify areas of progress and areas where opportunities for further improvement exist. The strategies with the greatest potential for reducing feto-infant mortality can be determined through further analysis of factors related to Maternal Health, Maternal Care, Newborn Care, and Infant Care.² This approach was initially developed by the WHO Collaborating Center in Perinatal Care, and has been applied in both developing and developed countries. The Canadian Perinatal Surveillance System of Health Canada has used the framework to estimate preventable feto-infant mortality in Canada.^{4,20} In the United States, the CityMatCH program, in collaboration with CDC and the March of Dimes, has used a modified version of this framework, which they refer to as the *Perinatal Periods of Risk Approach*, to study fetal and infant mortality in selected cities in order to help these urban areas shift their mortality prevention efforts from simple broad-based initiatives to more targeted effective strategies.^{12,21}

In Manitoba, there are encouraging trends in the feto-infant mortality rates – notable, the reduction of 20% in the overall rate between 1985 and 1998, and declines in all four risk-factor categories. This decline in mortality rates is consistent with trends in Canada and other developed countries.^{3,5,13}

There are also opportunities for improvement in Manitoba's feto-infant mortality rates. There are significant regional disparities, with higher mortality in some North Rural and South Rural regions in particular. These intra-provincial variations are consistent with the substantial variations in fetal, neonatal, and especially post-neonatal mortality rates found among the provinces and territories in Canada.⁴ In comparison to a benchmark urban sub-population, there is excess feto-infant mortality in all four categories and in almost all regions of the province of Manitoba. The greatest excess feto-infant mortality, and therefore the largest opportunity gap, is in the Infant Care (1.36 per 1000) and the Maternal Health (1.26 per 1000) areas. The smallest opportunity gaps are in the areas of Maternal Care and Newborn Care, suggesting that the health care system is functioning fairly well in these areas. However, one of the North Rural RHAs has higher rates of late stillbirths, indicating that there may be room for improvement in the area of Maternal Care provided to pregnant women in that region.

Because the Maternal Health and Infant Care categories have the highest feto-infant mortality rates (4.02 and 2.52 deaths per 1000 live births, respectively), as well as the greatest excess feto-infant mortality rates for Manitoba as a whole, efforts to reduce the provincial feto-infant mortality rate should be concentrated in these areas. Understanding the known risk factors and causes of mortality within these categories is key to identifying methods of reducing excess mortality. Excess feto-infant mortality in the Maternal Health category suggests a need to better understand the determinants of preterm birth, since approximately 98% of very low birthweight infants are born preterm.²² Preterm birth is associated with a number of modifiable risk factors, including smoking, substance abuse, low rate of weight gain during pregnancy, anaemia, urogenital infections,

strenuous work, domestic violence, stress, and inadequate prenatal care.^{11,23,24} In addition, preterm birth has been linked to socioeconomic factors, and is more frequent among the socially disadvantaged.^{10,11} Further analysis needs to focus on the prevalence and population-attributable risk associated with these modifiable risk factors, to help direct program planning. Because preterm birth prevention efforts directed toward women at high risk have been ineffective,^{25,26} a population health approach to reduce preterm birth has been proposed.²⁴

Analysis of excess deaths in the Infant Care category includes examining the underlying causes of infant death and assessing the prevalence of known risk factors and interventions by specific causes of death.²¹ The top three causes of post-neonatal mortality for Manitoba are sudden infant death syndrome (SIDS), congenital anomalies, and injuries. Deaths due to SIDS and injuries and some congenital anomalies have known modifiable risk factors, and more intensive promotion of known preventive practices is warranted. For example, preventive practices to reduce SIDS include decreasing use of the prone sleeping position for infants, eliminating exposure to second-hand smoke, and increasing breastfeeding rates,²⁷ while pre-conception use of folic acid supplements reduces the risk of neural tube defects²⁸ and safety measures can be implemented to reduce infant deaths due to injuries. In addition, underlying determinants of these outcomes, such as low socioeconomic status and environmental conditions, should be addressed.

This study provides evidence of socioeconomic disparities in perinatal outcomes. We found that women living in the lowest income tertile areas have higher infant mortality rates than women in the highest income tertile areas. This is comparable to the overall Canadian situation, in which infant mortality rates in Canada's poorest neighbourhoods were found to be two thirds higher than those in the richest neighbourhoods.⁵ Social approaches to lowering infant mortality are warranted.²⁹ In addition, the scope of information that is routinely collected through perinatal surveillance needs to be expanded to include maternal socioeconomic indicators, such as income and education.

There are limitations to the analyses of feto-infant mortality inherent in the data available and the scope of the conceptual framework. Pregnancies and deliveries not resulting in hospital outcomes are not captured in the Manitoba Perinatal Database and are therefore excluded; however, to date the number of home deliveries in Manitoba comprise less than 1% of the total. The 16-cell table places a gestational age restriction on fetal deaths, resulting in exclusion of early fetal deaths (less than 28 weeks gestation) from the analysis.¹² Future expansion of the framework to include analysis of early fetal deaths is warranted, since most countries include fetal deaths of 20 weeks gestation or greater in their fetal mortality rates. Two other major groups of adverse pregnancy outcomes excluded from this analysis include spontaneous abortions and therapeutic abortions, which account for approximately one quarter of hospital-based pregnancy outcomes in Manitoba.¹⁷ In addition, classifying fetal and infant deaths using this conceptual approach may not be entirely appropriate for some deaths, such as those due to congenital anomalies.²⁰

Other limitations relate to the fact that this conceptual framework is only a framework for surveillance. Any results related to excess feto-infant mortality need to be followed up with in-depth analysis of the reasons for excess deaths, including prevalence of known risk factors, availability of appropriate health care services, and causes of mortality, to provide sufficient direction for program planning and policy making. In addition, the link between assignment of birthweight and age at death within the 16-cell table, and the classification of determinants of perinatal outcomes into the four categories of Maternal Health, Maternal Care, Newborn Care, and Infant Care, requires further validation. Further testing is needed to determine whether the majority of deaths in each of these categories are largely attributable to factors in that category. For example, are excess deaths at birthweights of less than 1500 grams primarily attributable to a higher frequency of preterm births related to behavioural, social, health and economic disparities of the mothers, or to higher mortality rates once born at that birthweight related to quality of neonatal intensive care?²¹ A preliminary validation of the conceptual

framework by CityMatCH concluded that the grouping of cells in the framework fairly closely aligned with the grouping created when cells were clustered by cause of death and maternal risk factors, although insufficient information was available from vital records to adequately cluster fetal deaths.¹² Finally, this framework focuses on one component of surveillance data, feto-infant mortality. Other types of frameworks should be developed and tested to improve the impact of perinatal health surveillance data.

SUMMARY

The results of the application of this conceptual framework to Manitoba data are currently being shared with a broad range of stakeholders in perinatal health, including governmental, non-governmental and community groups. Because the greatest excess feto-infant mortality and opportunities for improvement were observed in the Infant Care and Maternal Health categories, attention to the broader determinants of health which influence these categories will be required. The smaller opportunity gaps in the Maternal and Newborn Care categories, which refer to health care variables, suggest that the health care system, with the possible exception of the North, is functioning well in these areas.

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RÉSUMÉ

Contexte : Les systèmes de surveillance médicale périnatale n'ont pas encore les cadres conceptuels nécessaires pour que leurs données puissent étayer la planification des politiques et des programmes. On montre ici comment appliquer un cadre conceptuel à l'analyse des données sur la mortalité fœto-infantile au Manitoba.

Méthode : Les cas de mortalité fœtale et infantile ont été classés dans une matrice bidimensionnelle (poids à la naissance/âge au décès) et regroupés en quatre grandes catégories de facteurs contribuant à la santé périnatale : Santé maternelle, Soins aux mères, Soins aux nouveau-nés et Soins aux nourrissons. On a calculé les taux de mortalité en proportion du poids à la naissance pour chaque catégorie et estimé la surmortalité fœto-infantile évitable par comparaison avec une sous-population de référence.

Résultats : Entre 1985 et 1998, la mortalité fœto-infantile a baissé au Manitoba, passant de 12,3 à 9,8 décès pour 1 000 naissances. La majeure partie de cette baisse a été enregistrée dans la catégorie des soins aux nouveau-nés; les décès attribuables à la santé maternelle et aux soins aux nourrissons ont très peu diminué. La comparaison du taux de mortalité fœto-infantile au taux de référence a mis en lumière une surmortalité de 3,46 décès pour 1 000 naissances, soit une possibilité d'amélioration de 33 %. On observe d'importants écarts régionaux dans les taux de mortalité fœto-infantile.

Résumé : L'application de ce cadre conceptuel fournit des renseignements utiles à la planification des politiques et des programmes. Comme la surmortalité fœto-infantile la plus importante a été observée dans les catégories Santé maternelle et Soins aux nourrissons, il faudra s'intéresser de plus près aux déterminants généraux de la santé qui influent sur ces catégories.