Title

Perinatal risk factors associated with gastroenteritis hospitalisations in Aboriginal and non-Aboriginal children in Western Australia (2000-2012): a record linkage cohort study

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Keywords

Gastroenteritis, diarrhoea, record linkage, hospitalisations, children

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Conflicts of interest

None to declare

Author contributions

TLS, HCM, CSW, DL and CCB conceptualised and designed the study. PF cleaned the data and conducted the analyses with advice from TLS, HCM, NdK and CCB. PF wrote the first draft of the manuscript. All authors have critically reviewed the manuscript and approved of the final version as submitted.

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Abstract

Background

Gastroenteritis is a leading cause of childhood morbidity worldwide. We aimed to assess the maternal and infant characteristics and population attributable fractions (PAFs) associated with childhood gastroenteritis-related hospitalisations.

Methods

We conducted a whole-of-population retrospective birth cohort study of 367,476 children live-born in Western Australia (WA) 2000-2012. We identified hospital admissions pertaining to these children, with a principal diagnosis code for infectious gastroenteritis. Cox regression was used to obtain the adjusted hazard ratios with 95% confidence intervals (CIs) and the PAFs associated with each risk factor in Aboriginal and non-Aboriginal children for their first gastroenteritis hospital admission.

Results

There were a total of 15,888 gastroenteritis-related hospital admissions (25.7% occurring among Aboriginal children). The overall gastroenteritis hospitalisation rate for children aged ≤14 years was 4.6/1000 child-years for non-Aboriginal children and 21.5/1000 child-years for Aboriginal children. Male gender, maternal age <20 years, pre-term birth, low birthweight, residence in remote regions of WA and birth in the pre-rotavirus vaccine era were significant independent risk factors for gastroenteritis hospitalisation in both Aboriginal and non-Aboriginal children. Being born in the pre-rotavirus vaccine era accounted for up to 39% (95%CI: 34.0-41.2) of all first gastroenteritis hospitalisations in the population. In Aboriginal children, residing in very remote regions of WA accounted for 22% (20.9-23.2) of initial admissions.

Conclusions

Given the beneficial effect of infant rotavirus vaccination in preventing all-cause gastroenteritis hospitalisation, efforts should be taken to target those at highest risk.

Introduction

Gastroenteritis (diarrhoea) is a leading cause of childhood morbidity worldwide. In 2010 there were an estimated 1.73 billion healthcare attendances for gastroenteritis among children aged less than 5 years old worldwide, including 36 million hospitalisations. In 2011 there were an estimated 700,000 gastroenteritis-related deaths.[1] The burden of gastroenteritis is highest in developing countries where the mortality is also high. Although gastroenteritis-related deaths are rare in developed countries, it remains one of the most frequent causes of hospitalisation in young children.[1]

In Western Australia (WA), gastroenteritis was found to be the second most common infection-related cause of hospitalisation after acute lower respiratory infections in young children.[2] The annual rate of hospitalisation for acute gastroenteritis in children less than 5 years old in WA was estimated to be 17 per 1000 children in 2006.[3] Gastroenteritis hospitalisation rates among Aboriginal and Torres Strait Islander (henceforth referred to as Aboriginal) children in WA are up to 7.6 times higher than in non-Aboriginal children.[3]

A range of pathogens – bacteria (Salmonella and Campylobacter species being most common), viruses (commonly norovirus and rotavirus) and protozoa (giardia and cryptosporidium) - cause gastroenteritis.[4-7] Two oral live attenuated rotavirus vaccines, RV1 (Rotarix® - GlaxoSmithKline Biologicals, Rixensart, Belgium) and RV5 (RotaTeq® - Merck Vaccines, Whitehouse Station, New Jersey, USA) were included in the Australian National Immunisation Program (NIP) in July 2007 for use in all infants from 6 weeks old. Since 2007, studies have shown declines in both all-cause gastroenteritis- and rotavirus-related hospitalisations in Australia for both Aboriginal and non-Aboriginal children, although as a

proportion of baseline rates the observed decline has been smaller among Aboriginal children.[8-11]

Identification of risk factors for acute gastroenteritis is central to the implementation of targeted preventive public health policies. Community and societal factors like crowded living conditions, day care attendance, diet, antibiotic and antacid use, malnutrition, proximity to domestic animals, and zinc deficiency have been identified as possible risk factors for childhood gastroenteritis.[5,12,13] Studies have investigated the individual and combined effect of breastfeeding, birth via caesarean section, and gestational age on childhood gastroenteritis hospitalisations.[14-17] A previous population-based study examined a multitude of perinatal risk factors associated with infant hospitalisations for viral gastroenteritis but not for all-cause gastroenteritis.[18] Also, it is unknown whether risk factors for gastroenteritis hospitalisation differ between Aboriginal and non-Aboriginal children. We aimed to investigate perinatal risk factors associated with gastroenteritis hospitalisation in a population birth cohort of children in WA and to explore the differences in these risk factors between Aboriginal and non-Aboriginal children.

Methods

WA has a total population of 2.6 million (as of December 2015), 3.6% of whom identify as Aboriginal. We conducted a retrospective cohort study of probabilistically linked administrative population-based health data using the Western Australian data linkage system.[19]

Study population and data sources

We included all children live-born in WA between January 1, 2000 and December 31, 2012. The birth cohort was identified through the Midwives' Notification System (MNS) and the Birth and Death Registries. The MNS records details of any midwife-attended birth of at least 20 weeks gestation, including live births and stillbirths, within WA. Along with socio-demographic information, the dataset also includes maternal medical and obstetric history, details of labour and delivery, characteristics of the child at birth, and infant outcomes as recorded by the attending midwife or physician. The birth registry consists of socio-demographic information of both parents and child as recorded by the parents.

All hospital records pertaining to children in the birth cohort were sourced and linked by the Western Australian Data Linkage Branch (WA DLB) from the Hospital Morbidity Data Collection (HMDC) which contains information on all inpatient separations from public and private hospitals across WA. The information include socio-demographic particulars, dates of admission and separation (discharge), details of transfers and discharge diagnosis codes (principal diagnosis, co-diagnosis and up to 20 additional diagnosis codes) using the International Classification of Diseases and Related Health problems, Tenth Revision, Australian Modification (ICD-10-AM) coding system. Any hospital admission within 48 hours of birth was excluded from all analyses.

Variables of interest

The study outcome was all hospital records which had an acute gastroenteritis-related ICD-10-AM code (A00-A09) in the principal diagnosis field, and had an admission and separation date between January 2000 and June 2014. Inter-hospital transfers and transfers within the same hospital, with the same principal diagnosis, were grouped into a single hospital admission. Gastroenteritis admissions within 14 days of a previous gastroenteritis admission having the same principal diagnosis code were grouped together and classified as a single episode of illness. These are hereafter referred to as gastroenteritis hospitalisations.

Maternal variables included in the analyses were maternal age at the time of her child's birth (<20 years, 20-24 years, 25-29 years, 30-34 years and ≥35 years), maternal smoking during pregnancy (yes/no), number of previous pregnancies as a proxy for presence of older siblings (0, 1 and ≥2), multiple birth (yes/no), mode of delivery (vaginal, instrumentation, elective caesarean and emergency caesarean), season of birth, Index of Relative Socio-economic Advantage and Disadvantage (IRSAD), and the Accessibility/Remoteness Index of Australia (ARIA). The IRSAD is one of the four Socio-Economic Indexes for Areas (SEIFA) derived by the Australian Bureau of Statistics (ABS). Each index measures a different aspect of the socio-economic conditions of the people living in a particular area and ranks the different geographical areas across Australia according to a score that is created based on the socio-economic characteristics in that area.[20] The IRSAD score is derived from 21 different variables which include low or high income, internet connection, skilled or unskilled occupations and education.[20] The IRSAD scores included in our analyses were based on the mother's residential address at the time of her child's birth. The scores were grouped into five categories ranging from most disadvantaged (<10% of the index scores) to least

disadvantaged (>90% of the index scores). ARIA is a standard national measure of geographic remoteness and access to services for localities and areas throughout Australia and is classified into major cities, inner regional, outer regional, remote and very remote.[21] Like the IRSAD, the ARIA classification used in this study was based on the mother's residential address at the time of her child's birth.

Aboriginal status of the child was identified using the derived Aboriginal status provided by WA DLB.[22] Child-related variables included in the analyses were sex, gestational age (<33 weeks, 33-34 weeks, 35-36 weeks and >=37 weeks) and whether eligible for rotavirus vaccine (yes/no; born on or after 1 May 2007). Proportion of optimal birth weight (POBW) is a calculated measure of the appropriateness of intrauterine growth which takes into account gestational age, maternal age, maternal height, parity and infant gender.[23] POBW was used rather than stand-alone birthweight and was classified into high (>=115%), normal (85-114%) and low (<85%).

Statistical analysis

Using all gastroenteritis hospitalisations as the numerator and person-time-at-risk (PTAR) as the denominator, age-specific incidence rates of acute gastroenteritis hospitalisations were calculated separately for Aboriginal and non-Aboriginal children. We calculated incidence rate ratios (IRRs) between Aboriginal and non-Aboriginal children across different age groups. Exact 95% confidence intervals (CI) and IRRs were calculated using EpiBasic (version 3).

Using time-to-first-event, Cox proportional hazards regression was used to calculate the adjusted hazard ratios (aHR) and the associated 95% confidence intervals (CIs) for the

association between the independent exposure variables and first gastroenteritis hospitalisation. Univariate analyses of each exposure variable were first conducted. The age of the child was used to measure the time to first hospitalisation for gastroenteritis. The censor date was set to the date of first hospitalisation for gastroenteritis, death, or end of the study period (30 June 2014), whichever occurred first. Separate models were constructed for Aboriginal and non-Aboriginal children.

Population attributable fractions (PAF) are estimates of the proportion of disease in the population that is attributable to a particular risk factor, accounting for both the prevalence of the risk factor in the population and the strength of its association with disease. Adjusted PAFs and their 95% CIs were calculated for each identified risk factor in our study using the *punafcc* command in STATA. Data cleaning was performed in IBM SPSS (version 23). All analyses were conducted using STATA (version 13.1).

Ethical approval

This study was conducted with approvals from the WA Department of Health Human Research Ethics Committee, the WA Aboriginal Health Ethics Committee and the University of Western Australia Human Research Ethics Committee.

Results

The birth cohort comprised 367,476 children, of whom 24,597 (6.7%) identified as Aboriginal. 1504 (0.4%) children died over the course of the study period. The total PTAR was 190,407 years for Aboriginal children and 2,592,760 years for non-Aboriginal children. The demographic and perinatal characteristics of the cohort are described in Table 1. Between January 2000 and June 2014, 13,881 children in the cohort (12.7% of all Aboriginal children and 3.1% of all non-Aboriginal children) were hospitalised at least once for gastroenteritis (Table 1). Of these, approximately 1 in 5 (670/3131; 21.4%) Aboriginal children were hospitalised more than once for gastroenteritis compared with 1 in 13 (813/10,750; 7.6%) in non-Aboriginal children giving a total of 15,888 gastroenteritis coded hospital admissions, of which 4086 (25.7%) occurred among Aboriginal children.

The median age at first admission for gastroenteritis was 390 days (inter-quartile range IQR: 215-683 days) for Aboriginal children and 551 days (IQR: 298-1049 days) in non-Aboriginal children (Table 1). The overall gastroenteritis hospitalisation rate (including all admissions) for children aged ≤14 years over the study period (2000-2014) was 21.5/1000 child-years for Aboriginal children and 4.6/1000 child-years for non-Aboriginal children. The gastroenteritis hospitalisation rate was 4.7 (95% CI: 4.6-4.9) times higher in Aboriginal children than in non-Aboriginal children. Hospitalisation rates for gastroenteritis were higher in children aged <2 years than in the older age groups, with the highest rates seen in children aged 6-11 months among both Aboriginal (78.8/1000 child-years, 95% CI: 73.9-83.9) and non-Aboriginal children (11.6/1000 child-years, 95% CI: 11.1-12.1; Table 2). Hospitalisation rates were higher in Aboriginal children than in non-Aboriginal children in all age groups with the greatest disparity in those aged 6-11 months (IRR 6.8, 95% CI: 6.3-7.3; Table 2). Over the course of the study period, hospitalisation rates declined across all ages in both

Aboriginal and non-Aboriginal children, although rates appear to have levelled off in recent years (Figure 1).

Further analyses examined risk factors for first hospitalisation for gastroenteritis. In the adjusted model for Aboriginal children, male gender, maternal age <25 years, pre-term birth <37 weeks, low birth weight, residence in regional/remote regions of WA and birth in the pre-rotavirus vaccine era were significant independent risk factors for hospitalisation for gastroenteritis (Table 3a). Aboriginal children living in the very remote regions of WA had 3.2 times the risk (95% CI: 2.8, 3.6) of hospitalisation compared to those living in the major cities. Among Aboriginal children, plurality of birth and mode of delivery were not associated with increased risk of hospitalisation for gastroenteritis.

In the adjusted model for non-Aboriginal children, male gender, singleton birth, maternal age <35 years, birth to multiparous women, pre-term birth <37 weeks, low birth weight, non-vaginal birth, socio-economic disadvantage, residence in non-metropolitan regions of WA and birth in the pre- rotavirus vaccine era were significant independent risk factors for gastroenteritis hospitalisation (Table 3b). Among non-Aboriginal children, those born at gestational age of <33 weeks had 2.1 times (95% CI: 1.9, 2.4) the risk of hospitalisation for gastroenteritis compared to those born ≥37 weeks of gestation; those born to mothers aged <20 years had nearly twice the risk of hospitalisation compared to those born to mothers aged >35 years, and those born by caesarean section had 1.2 times the risk of hospitalisation compared to those born by vaginal delivery.

The adjusted models showed that Aboriginal and non-Aboriginal children born in the rotavirus vaccine era had less than half the risk of hospitalisation for gastroenteritis compared

to those born in the pre-vaccine era (Tables 3a and 3b). Reported maternal smoking at birth was not associated with risk of hospitalisation for gastroenteritis in either Aboriginal or non-Aboriginal children after adjustment for other factors.

The combined PAF for Aboriginal children was 81.3% (95% CI: 73.0, 87.0), indicating that the risk factors included in the model could account for most of the hospitalisations for gastroenteritis. Adjusting for all other risk factors, the factors with highest PAFs were birth in the pre-rotavirus vaccine era (37.7%) and residence in very remote regions of WA (22.0%). Low birthweight accounted for 6.6% of the PAF and maternal age <20 years accounted for 6.1% in Aboriginal children (Table 3a). The combined PAF for non-Aboriginal children was 79.1% (95% CI: 74.8, 82.6). Similar to Aboriginal children, birth in the pre-rotavirus vaccine era accounted for a high PAF of 39.2% in non-Aboriginal children. Singleton births (PAF: 16.2%) and SEIFA score in the 26-75% category (PAF: 13.6%) also accounted for many of the hospitalisations. Adjusting for all other risk factors, non-Aboriginal children born to mothers in their early 20s accounted for 6.6% and birth by caesarean section accounted for nearly 3% of the hospitalisations (Table 3b).

Discussion

Gastroenteritis continues to be a cause of health disparity between Aboriginal and non-Aboriginal children with hospitalisation rates nearly 5 times higher in Aboriginal than non-Aboriginal children. The burden of gastroenteritis hospitalisation is significantly higher in children aged < 2 years than in older age groups among both Aboriginal and non-Aboriginal children, with the highest rates in those aged 6-11 months. This is consistent with earlier studies in WA that have shown rates of hospitalisation for gastroenteritis to be highest in very young children with Aboriginal children experiencing a greater burden than their non-Aboriginal counterparts across all age groups.[3,24,25]

This population-based study provides comprehensive data on the association between perinatal risk factors and gastroenteritis hospitalisations in an Australian cohort separately for Aboriginal and non-Aboriginal children. To our knowledge, this is the first study to report on PAFs associated with perinatal risk factors for gastroenteritis hospitalisations. PAFs provide a predicted estimate of the proportion of disease that can be averted by eliminating a particular risk factor and, from a public health perspective, highlight those modifiable risk factors that could be targeted by interventions. This analysis has pinpointed the similarities and differences in the level of association of the risk factors for gastroenteritis in Aboriginal and non-Aboriginal children. Although not all the risk factors in our study are preventable or even modifiable, these data highlight areas where interventions could be put in place to prevent gastroenteritis.

Globally, prior to the introduction of the rotavirus vaccine, nearly 39% of all gastroenteritis hospitalisations were attributable to rotavirus infection.[26] In Australia, declines have been seen not only in the rates of rotavirus-associated hospitalisation but also in the rates of all-

cause acute gastroenteritis hospitalisation in young children.[8-10] In our study gastroenteritis hospitalisation risk was reduced by more than 50% in both Aboriginal and non-Aboriginal children who were eligible for rotavirus vaccination. Although we did not have the individual vaccination status for each child in our cohort, annual vaccination coverage reports show that, since the inclusion of rotavirus vaccine in the NIP in 2007, around 80% of all children in WA are fully vaccinated against rotavirus by 12 months of age.[27] It is likely that a significant part of the reduction in all-cause gastroenteritis hospitalisations is attributable to vaccination, although it should be noted that hospitalisations were declining even before vaccine introduction. The highest PAFs in both Aboriginal and non-Aboriginal children were for children born in the pre-rotavirus vaccine era suggesting that up to 39% of all gastroenteritis hospitalisations in the population could be averted if all children receive rotavirus vaccine.

Non-Aboriginal children born to mothers aged <20 years old had nearly twice the risk of being hospitalised for gastroenteritis compared to children born to mothers aged >35 years old. An association between young maternal age and poor child health outcomes (including increased likelihood of hospitalisation for infection) has been documented previously but whether this association is due to a biological causal mechanism or is confounded by socioeconomic status is uncertain.[28,29] Although we have attempted to adjust for socioeconomic status in our study, we cannot exclude residual confounding by social and life-style factors such as living arrangements. For example, teenage mothers may be more likely to reside in multigenerational households with increased chance of exposure of their children to infection. Aboriginal children born to teenage mothers had 1.3 times higher risk of hospitalisation than children born to mothers aged ≥30 years. Though this risk is slightly lower than for non-Aboriginal children, nearly 6% of all gastroenteritis in Aboriginal children could be prevented if there were no births to teenage mothers (who represented nearly a

quarter of all Aboriginal mothers) as compared to only 3% in their non-Aboriginal counterparts. This highlights the importance of health promotion campaigns to create awareness about the risks associated with teenage pregnancies.

Delivery by caesarean section delays the early colonisation of the gut by 'beneficial' bacteria like *Bacteroides, Lactobcaillus* and *Bifidobacterium* spp. after birth which plays a role in the postnatal maturation and development of the immune system.[30] Consistent with this, vaginal birth was associated with decreased risk of hospitalisation for gastroenteritis in non-Aboriginal children and nearly 3% of all gastroenteritis could be prevented if there were no surgical deliveries in this population. Although there was no significant association between mode of delivery and gastroenteritis hospitalisation among Aboriginal children in the adjusted model, there was substantial overlap in the confidence intervals for these effects indicating that this difference could be due to the much smaller numbers of caesareans births among Aboriginal mothers. Nevertheless, the increased risk for gastroenteritis hospitalisation in children born by elective caesarean should be taken into consideration by parents and healthcare providers when deciding on delivery options.

Gestational age <33 weeks and low birth weight were independent risk factors for hospitalisation for gastroenteritis among both Aboriginal and non-Aboriginal children, consistent with studies in Australia and the United States that have demonstrated decreasing gestational age and low birth weight as risk factors for gastroenteritis-related hospitalisations.[17,18] Factors such as increased permeability of immature gut epithelium leading to easy invasion by pathogens, delayed intestinal colonisation by beneficial bacteria and immature/altered immune function in preterm and/or low birthweight children may contribute to a sustained increase in risk of gastroenteritis hospitalisation in these children. [31-

[33] In this study, in the presence of other risk factors, nearly 7% of gastroenteritis hospitalisations in Aboriginal children and approximately 3% in non-Aboriginal children are attributed to low birthweight. Pre-term birth and low birthweight are not entirely modifiable risk factors since the successful prevention of these factors by advocating strategies for healthy pregnancy depends on the underlying cause. In light of this, mothers with low birthweight or pre-term babies should be targeted for health promotion by healthcare providers.

A systematic study has shown that the association between socio-economic status and gastrointestinal infection in developed countries is unclear and varies across pathogens.[34] In our study, hospitalisation risk decreased with increasing levels of socio-economic advantage in non-Aboriginal children, with children in the most disadvantaged group having 1.5 times the risk compared to children in the most advantaged group. There was no evidence that socio-economic disparity has an independent effect on risk among Aboriginal children. Only 4% of Aboriginal children (compared to 26% of non-Aboriginal children) resided in the upper two quantiles of the IRSAD, so we may have been under-powered to demonstrate a significant effect of socio-economic status among Aboriginal children. The risk of gastroenteritis was threefold for Aboriginal children living in the very remote regions of WA and the associated PAF was 22%. This highlights the high proportion of gastroenteritis hospitalisations that could be potentially be prevented by improving access to services in this population.

Though maternal smoking during pregnancy has been found to be an independent dose-dependent risk factor for gastrointestinal illness in children elsewhere, whether this effect is mediated via the impact of smoking on birthweight and prematurity or other mechanisms is

unclear.[18,35,36] In our study, the association between maternal smoking and gastroenteritis hospitalisation was not evident after adjusting for other perinatal risk factors, suggesting the effects of smoking on gastroenteritis risk may be mediated through these other factors.

The strength of this study is that it is based on a large comprehensive population-based cohort using health administrative datasets of individual records that have been validated for accuracy.[37] The perinatal characteristics and risk factors were available for the whole cohort and not just for the children who were hospitalised. Also, since we have reliable data on Aboriginal status, we were able to compare hospitalisation rates and risk factors between Aboriginal and non-Aboriginal children.[22]

Our study has some limitations. The total burden of gastroenteritis in the community has not been ascertained in this study. Most episodes of gastroenteritis are managed at home or through out-patient facilities without warranting hospital admission. Since we did not include primary care data, we only captured the severe end of the clinical spectrum – gastroenteritis requiring hospitalisation. Also, the incidence of gastroenteritis hospitalisation in the cohort might be underestimated - only hospital records which had a gastroenteritis-specific ICD-10 diagnosis code listed in the principal diagnosis were selected for analysis. This is because we conservatively assumed gastroenteritis to be the primary reason for hospitalisation only if it was the first coded diagnosis. Furthermore, since we linked only hospitalisation records from WA, some hospitalisations may not have been ascertained, for example among those who travelled out of the state.

We lacked information about breastfeeding, day care attendance, living conditions and more direct measures of socioeconomic status (like household income) which have been shown

elsewhere to be risk factors.[13,17] Also, the risk factors for gastroenteritis hospitalisation might differ depending upon the microbial pathogen causing the episode of gastroenteritis. ICD-10 diagnosis codes have been shown to be insensitive for identifying pathogen-specific hospital admissions.[38]We would need to link laboratory pathology results for enteric pathogens to hospital records to measure pathogen specific burden of disease and determine pathogen-specific risk factors; this will form the focus of our future analyses.

In conclusion, the findings of this study highlight the continued burden of gastroenteritis in children in WA. Using a large population-based record linkage study, we have identified several maternal and neonatal risk factors associated with gastroenteritis hospitalisations in both Aboriginal and non-Aboriginal populations. Furthermore, the PAFs have highlighted areas that could benefit from a more targeted approach for intervention. The beneficial effect of infant rotavirus vaccination in preventing gastroenteritis hospitalisation is evident. Although rotavirus vaccination is universal in WA, efforts should be taken to target high risk population groups identified in this study including Aboriginal children, young mothers, pre-term and low birthweight infants, those delivered by surgical methods and those residing in remote regions of WA.

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Figure legends

Figure 1. Age-specific hospitalisation rates for acute gastroenteritis-coded hospitalisations in a) Aboriginal and b) non-Aboriginal children (2000-2012)

Table 1. Perinatal and socio-demographic characteristics of children born in Western Australia (2000-2012)

Perinatal and socio-demographic characteristics	Aboriginal N=24,597 (%)[a]	Non-Aboriginal N=342,879 (%)[a]
Number of children with at least 1 hospital admission for gastroenteritis	3,131 (12.7)	10,750 (3.1)
Median age in days at time of first admission (inter-quartile range)	390 (215-683)	551 (298-1049)
Male	12,526 (50.9)	175,336 (51.1)
Maternal age		
<20 years	5,598 (22.7)	13,009 (3.8)
20-24 years	7,961 (32.4)	49,783 (14.5)
25-29 years	5,899 (24.0)	97,004 (28.3)
30-34 years	3,375 (13.7)	112,685 (32.9)
≥35 years	1,764 (7.2)	70,398 (20.5)
Maternal smoking during pregnancy	11,851 (48.3)	47,495 (13.9)
Gestational age		
<33 weeks	821 (3.3)	4,855 (1.4)
33-34 weeks	727 (3.0)	5,490 (1.6)
35-36 weeks	2,039 (8.3)	17,397 (5.1)
≥37 weeks	21,010 (85.2)	315,137 (91.9)
Mode of delivery		
Vaginal	17,243 (70.1)	180,862 (52.8)
Instrumentation	1,858 (7.6)	50,184 (14.6)
Elective caesarean	2,100 (8.5)	63,072 (18.4)

Emergency caesarean	3,360 (13.7)	48,517 (14.2)
Percent optimal birthweight		
Low <85%	5,326 (21.7)	35,104 (10.2)
Normal 85-114%	14,826 (60.3)	236,412 (69.0)
High ≥115%	1,595 (6.5)	29,603 (8.6)
Multiple birth	606 (2.5)	10,257 (3.0)
Season of birth		
Spring	5,851 (23.8)	86,209 (25.1)
Summer	6,148 (25.0)	83,601 (24.4)
Autumn	6,489 (26.4)	87,699 (25.6)
Winter	6,109 (24.8)	85,370 (24.9)
SEIFA Index of Advantage and disadvantage		
0-10% (most disadvantaged)	7,245 (33.8)	24,173 (7.6)
11-25%	5,656 (26.4)	48,726 (15.3)
26-75%	7,580 (35.4)	165,182 (51.7)
76-90%	796 (3.7)	55,579 (17.4)
91-100% (least disadvantaged)	139 (0.7)	25,708 (8.1)
Accessibility/remoteness Index of Australia		
Major cities	7,871 (32.0)	236,753 (69.1)
Inner regional	1,606 (6.5)	38,493 (11.2)
Outer regional	3,829 (15.6)	26,726 (7.8)
Remote	3,807 (15.5)	11,865 (3.5)
Very remote	3,638 (14.8)	3,434 (1.0)

[a] Percentages may not always add up to 100 due to missing values

Table 2. All-cause gastroenteritis hospital admission rates per 1000 child years and incidence rate ratios (IRRs) comparing Aboriginal and non-Aboriginal children aged <15 years (2000-2014)

Age group	Aboriginal		Non-Aboriginal		IRR (95%CI)[a]
	n	Rate (95% CI)[a]	n	Rate (95% CI)[a]	
<6 months	710	58.1 (54.0, 62.5)	1623	9.5 (9.0, 10.0)	6.1 (5.6, 6.7)
6-11 months	960	78.8 (73.9, 83.9)	1982	11.6 (11.1, 12.1)	6.8 (6.3, 7.3)
12-23 months	1365	56.6 (53.7, 59.7)	3495	10.3 (10.0, 10.7)	5.5 (5.1, 5.8)
2-4 years	784	12.8 (11.9, 13.7)	3330	4.0 (3.8, 4.1)	3.2 (3.0, 3.5)
5-9 years	236	3.8 (3.3, 4.3)	1203	1.4 (1.4, 1.5)	2.6 (2.8, 3.0)
10-14 years	31	1.8 (1.2, 2.5)	169	0.7 (0.6, 1.5)	2.4 (1.7, 3.6)
Total	4086	21.5 (20.8, 22.1)	11802	4.6 (4.5, 4.6)	4.7 (4.6, 4.9)

[a] CI: Confidence interval

Table 3a. Univariate and adjusted hazard ratios (aHR) and adjusted population attributable fractions (PAFs) for risk factors for gastroenteritis hospitalisation in Aboriginal children in WA

Risk factors	Univariate[a]		Adjusted		Adjusted	
	HR	95% CI	aHR	95% CI	PAF%	95% CI
Baby gender						
Female	*Ref*					
Male	1.12	1.04, 1.20	1.12	1.03, 1.22	5.80	1.64, 9.78
Maternal age						
<20 years	1.19	1.05, 1.33	1.34	1.12, 1.60	6.03	2.82, 9.14
20-24 years	1.07	0.95, 1.20	1.18	1.02, 1.37	4.99	0.91, 8.90
25-29 years	1.00	0.88, 1.13	1.09	0.94, 1.27	2.05	-1.24, 5.22
30-34 years	*Ref*					
≥35 years	1.06	0.89, 1.25	1.22	1.00, 1.48	1.32	0.10, 2.53
Maternal smoking during pregnancy						
No	*Ref*					

Yes	1.14	1.06, 1.22	1.00	0.91, 1.09	0.20	-4.76, 4.17
Number of previous pregnancies						
0	1.13	1.01, 1.25	1.05	0.91, 1.21	1.01	-1.91, 3.84
1	*Ref*					
≥2	1.05	0.96, 1.15	1.11	0.99, 1.26	5.94	-0.68, 12.13
Gestational age						
≥37 weeks	*Ref*					
35-36 weeks	1.27	1.12, 1.42	1.26	1.09, 1.45	2.10	0.91, 3.28
33-34 weeks	1.17	0.96, 1.42	1.16	0.92, 1.47	0.51	-0.23, 1.24
<33 weeks	1.22	1.01, 1.47	1.34	1.07, 1.68	1.03	0.35, 1.71
Mode of delivery						
Vaginal	*Ref*					
Instrumentation	0.98	0.85, 1.13	1.06	0.89, 1.26	0.40	-0.76, 1.55
Elective caesarean	0.96	0.84, 1.09	1.06	0.90, 1.24	0.48	-0.79, 1.73
Emergency caesarean	1.14	1.03, 1.26	1.08	0.95, 1.23	1.04	-0.64, 2.68
Plurality						

Singleton	*Ref*					
Multiple birth	1.24	1.01, 1.52	1.18	0.92, 1.51	5.28	-0.20, 1.25
Proportion of optimal birthweight						
High ≥115%	*Ref*					
Normal 85-114%	0.98	0.85, 1.14	1.10	0.92, 1.31	5.92	-5.16, 15.83
Low <85%	1.28	1.10, 1.50	1.31	1.08, 1.58	6.57	2.41, 10.56
Season of birth						
Winter	*Ref*					
Spring	1.06	0.95, 1.17	1.04	0.91, 1.17	0.79	-2.02, 3.51
Summer	1.11	1.00, 1.22	1.04	0.92, 1.18	1.01	-2.01, 3.93
Autumn	1.13	1.03, 1.25	1.06	0.94, 1.19	1.49	-1.74, 4.62
SEIFA Index of Advantage and disadvantage						
0-10% (most disadvantaged)	1.40	1.05, 1.86	1.27	0.96, 1.69	8.14	-0.75, 16.25
11-25%	1.11	0.83, 1.48	1.24	0.93, 1.65	4.68	-1.02, 10.06
26-75%	0.99	0.74, 1.32	1.24	0.93, 1.63	6.60	-1.60, 14.14
76-90%	*Ref*					

91-100% (least disadvantaged)	1.00	0.53, 1.89	1.25	0.67, 2.35	0.12	-0.17, 0.40
Accessibility/remoteness Index of Australia						
Major cities	*Ref*					
Inner regional	1.01	0.82, 1.24	1.00	0.81, 1.23	0.01	-1.08, 1.04
Outer regional	1.71	1.51, 1.94	1.73	1.52, 1.97	8.01	6.55, 9.44
Remote	1.67	1.47, 1.89	1.69	1.48, 1.93	7.29	5.87, 8.69
Very remote	3.29	2.95, 3.66	3.18	2.83, 3.58	22.04	20.86, 23.21
Born on/after 1 May 2007						
Yes	*Ref*					
No	2.11[b]	1.95, 2.28	2.04	1.85, 2.26	37.73	34.02, 41.22

HR - Unadjusted hazard ratio aHR - Adjusted hazard ratio PAF - population attributable fraction

[a] All adjusted for year of birth [b] Not adjusted for year of birth

Table 3b. Univariate and adjusted hazard ratios (aHR) and adjusted population attributable fractions (PAFs) for risk factors for gastroenteritis hospitalisation in non-Aboriginal children in WA

Risk factors	Univariate[a]		Adjusted		Adjusted	
	HR	95% CI	aHR	95% CI	PAF%	95% CI
Baby gender						
Female	*Ref*					
Male	1.11	1.07, 1.16	1.11	1.07, 1.16	5.37	3.32, 7.38
Maternal age						
<20 years	1.99	1.83, 2.18	1.97	1.77, 2.19	3.12	2.78, 3.46
20-24 years	1.57	1.48, 1.68	1.54	1.43, 1.67	6.60	5.68, 7.52
25-29 years	1.27	1.20, 1.35	1.28	1.19, 1.36	6.40	4.83, 7.94
30-34 years	1.08	1.02, 1.15	1.10	1.03, 1.17	2.60	0.84, 4.33
≥35 years	*Ref*					
Maternal smoking during pregnancy						
No	*Ref*					

Yes	1.16	1.10, 1.22	1.00	0.94, 1.05	0.09	-1.12, 0.94
Number of previous pregnancies						
0	*Ref*					
1	0.94	0.89, 0.98	1.03	0.97, 1.09	0.89	-0.80, 2.53
≥2	0.93	0.89, 0.98	1.06	1.01, 1.13	2.30	0.24, 4.33
Gestational age						
≥37 weeks	*Ref*					
35-36 weeks	1.26	1.17, 1.37	1.30	1.19, 1.43	1.49	1.06, 1.92
33-34 weeks	1.41	1.24, 1.60	1.39	1.20, 1.61	0.61	0.38, 0.84
<33 weeks	2.03	1.80, 2.29	2.13	1.86, 2.43	1.48	1.31, 1.66
Mode of delivery						
Vaginal	*Ref*					
Instrumentation	1.07	1.01, 1.13	1.13	1.06, 1.21	1.61	0.81, 2.42
Elective caesarean	1.06	1.01, 1.12	1.19	1.12, 1.26	2.83	1.94, 3.71
Emergency caesarean	1.24	1.18, 1.31	1.23	1.15, 1.31	2.94	2.13, 3.74
Plurality						

Singleton	0.95	0.85, 1.05	1.20	1.06, 1.36	16.18	5.57, 25.60
Multiple birth	*Ref*					
Proportion of optimal birthweight						
High ≥115%	*Ref*					
Normal 85-114%	1.02	0.95, 1.09	1.08	1.01, 1.17	5.93	0.60, 10.97
Low <85%	1.21	1.11, 1.31	1.23	1.12, 1.35	2.55	1.54, 3.54
Season of birth						
Winter	1.02	0.96, 1.07	1.03	0.97, 1.09	0.76	-0.66, 2.16
Spring	1.00	0.95, 1.06	1.03	0.97, 1.10	0.79	-0.61, 2.17
Summer	1.04	0.98, 1.09	1.03	0.97, 1.09	0.67	-0.76, 2.08
Autumn	*Ref*					
SEIFA Index of Advantage and disadvantage						
0-10% (most disadvantaged)	1.73	1.56, 1.92	1.54	1.37, 1.73	3.56	2.80, 4.32
11-25%	1.70	1.55, 1.86	1.56	1.40, 1.73	6.68	5.42, 7.92
26-75%	1.43	1.31, 1.56	1.36	1.24, 1.50	13.56	9.89, 17.09
76-90%	1.26	1.15, 1.39	1.28	1.15, 1.42	3.21	2.01, 4.40

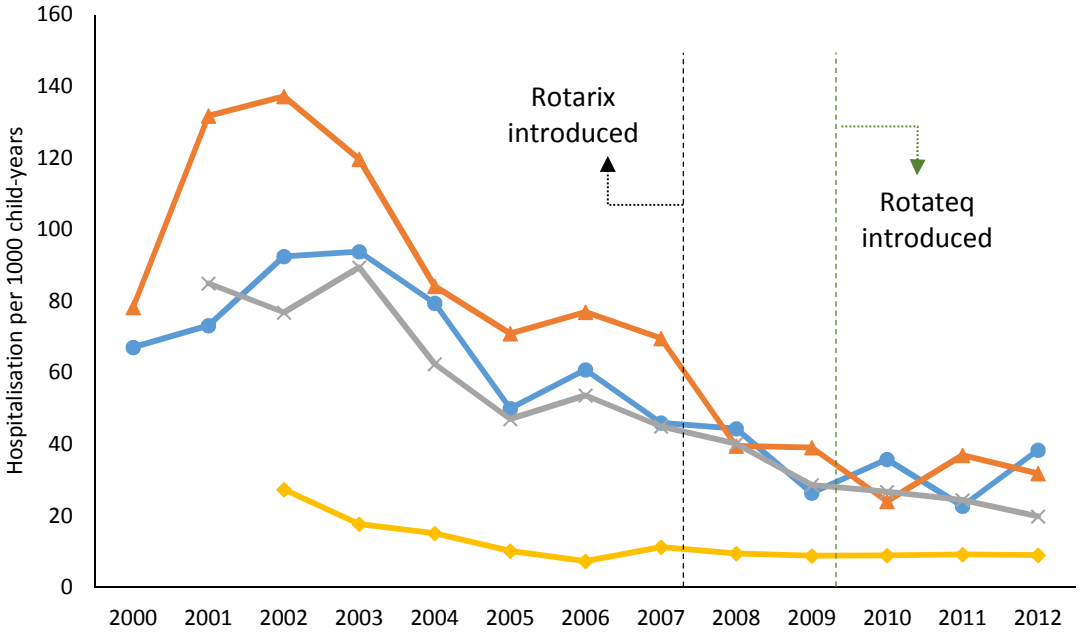
91-100% (least disadvantaged)	*Ref*					
Accessibility/remoteness Index of Australia						
Major cities	*Ref*					
Inner regional	1.17	1.10, 1.25	1.09	1.02, 1.16	1.05	0.29, 1.80
Outer regional	1.46	1.37, 1.55	1.39	1.30, 1.49	3.19	2.63, 3.74
Remote	1.24	1.12, 1.36	1.22	1.10, 1.36	0.77	0.41, 1.12
Very remote	1.47	1.24, 1.73	1.43	1.20, 1.72	0.41	0.24, 0.58
Born on/after 1 May 2007						
Yes	*Ref*					
No	2.08[b]	1.99, 2.17	2.09	1.99, 2.19	39.24	37.43, 41.00

HR - Unadjusted hazard ratio aHR - Adjusted hazard ratio PAF - population attributable fraction

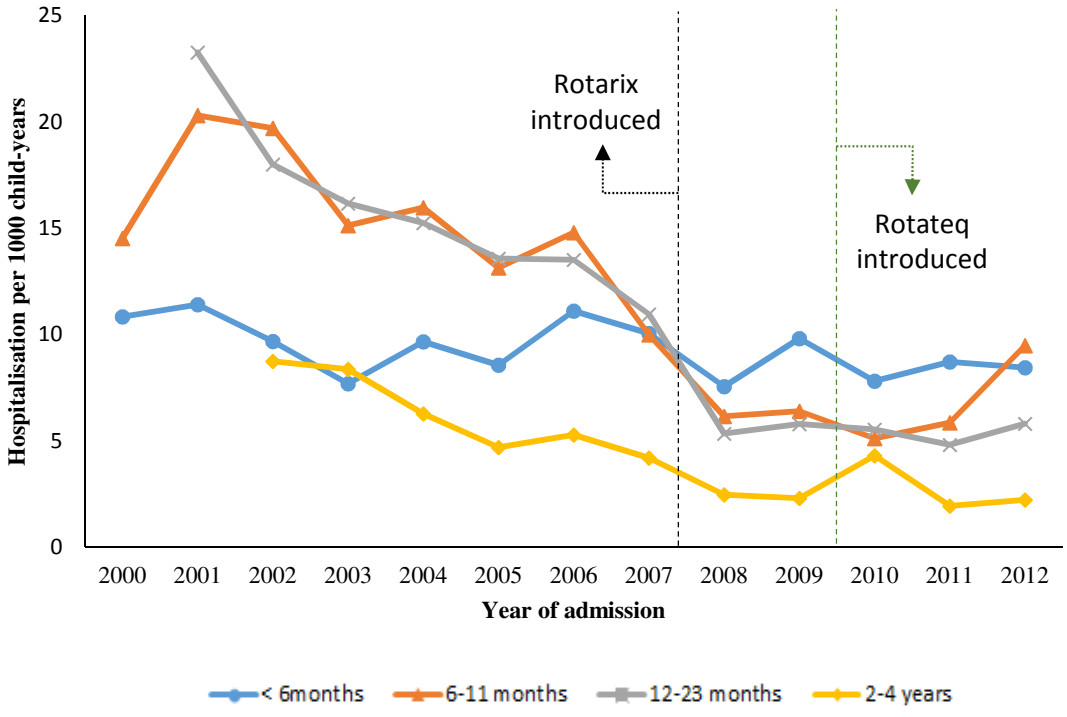
[a] All adjusted for year of birth [b] Not adjusted for year of birth

Figure 1. Age-specific hospitalisation rates for acute gastroenteritis-coded hospitalisations in a) Aboriginal and b) non-Aboriginal children (2000-2012)

a)



b)



* Note the difference in y-axis scale