Infection Is the Major Component of the Disease Burden in Aboriginal and Non-Aboriginal Australian Children

A Population-Based Study

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Background: Infection accounts for the majority of pediatric mortality and morbidity in developing countries, but there are limited data on the infectious diseases burden in children from developed countries. We investigated reasons for hospitalization before age 2 years in a birth cohort of Western Australian Aboriginal and non-Aboriginal children.

Methods: Data on live births between January 1990 and December 2000, and corresponding deaths and hospitalizations in the first 2 years of life, were obtained through linked population-based data.

Results: Almost half the cohort of 270,068 children were hospitalized at least once. Aboriginal children had significantly higher admission rates (2196 vs. 779 per 1000 live births), stayed longer and were more likely to die in hospital than non-Aboriginal children. Infections (mainly respiratory and gastrointestinal) were the most common reason for hospitalization, accounting for 34% of all admissions, with higher rates in Aboriginal (1114 per 1000 live births) than non-Aboriginal children (242 per 1000) ($P < 0.001$). Over time, admission rates for infections declined in Aboriginal children but increased in non-Aboriginal children. Aboriginal children were admitted 14 times more often for pneumonia than non-Aboriginal children.

Conclusions: Infections are the leading cause of hospitalization in children under 2 years of age. The continuing heavy burden of serious infections, borne disproportionately by Aboriginal children, needs to be alleviated. Public health interventions such as the development and universal implementation of vaccines for respiratory syncytial virus, rotavirus and influenza are needed, while adequate funding must be committed to Indigenous health services and training.

Key Words: linked population health data, indigenous, hospital admission, infection, Aboriginal Australian children

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There is a dearth of cause-specific population-based childhood morbidity data internationally, particularly for indigenous populations in industrialized countries. Total population data are a valuable resource on which to base policies, manage health services and evaluate interventions. Indigenous populations in industrialized countries have much worse health outcomes than nonindigenous populations^{1,2}; data thus need to be analyzed separately for these populations to enable focused policies and differential use of resources. Available data indicate that infections are an important cause of child morbidity and mortality. Infection accounts for over half of the 10 million deaths of children under 5 years of age around the world.³ Recent examination of total population data from Western Australia (WA) show that Aboriginal children are 4.5 times more likely to die before age 1 year but 9 times more likely to die of an infection than non-Aboriginal children.⁴ Existing population-based hospital morbidity studies highlight the importance of respiratory and gastrointestinal infections.^{5–8} However, there are few studies that compare the importance of infection with other causes of morbidity and the relative importance of various infectious diseases.

Record linkage of administrative health data offers a powerful resource of data about the total population, which, in addition to informing policies and evaluating interventions, may also be used to investigate causal pathways and consequences of diseases.^{9,10} The WA Data Linkage System (WADLS) is one of a very few such resources worldwide, based on a stable population with validated identification of indigenous status.^{11,12} We used these data to describe the reasons for hospitalization before age 2 years in a total population birth cohort (1990–2000) in WA, ranking infection and other causes of morbidity and examining the different types of admission for infection in Aboriginal and non-Aboriginal children.

MATERIALS AND METHODS

Setting and the WA Data Linkage System. WA covers an area of 2.5 million km² (around 4 times the size of Texas) and in

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2001 had a population of 1.8 million, 3% of whom identified as Aboriginal or Torres Strait Islander.¹³ The WA Department of Health has classified postcodes into metropolitan (including the state capital, Perth), rural and remote areas. Children were assigned to metropolitan, rural and remote regions based on the postcode of residence and following the Health Zone classification of the WA Department of Health. This is defined broadly by distance from Perth.

The WADLS links all births, hospital admissions and deaths in the state.^{11,14} We identified singleton live births in WA between January 1, 1990 and December 31, 2000. Children born to women who were not resident in WA ($n = 294$) and children of unknown gender at birth ($n = 24$) were excluded. Place of residence was obtained from one of the components of the WADLS, the Midwives' Notification System, which is complete for >99% of all births in WA. The term Aboriginal is used to describe people identifying as either Aboriginal and/or Torres Strait Islander. Children were identified as Aboriginal if their mother was identified as such on the Midwives' Notification System, which is recognized as the most reliable source of data on Aboriginality.¹² Hospital admissions, of at least one night's duration, for an illness recorded for the child between birth and 2 years of age (1990-2002) were examined using the linked data.

The Australian version of the International Classification of Diseases, 9th revision, Clinical Modification (ICD-9-CM)¹⁵ was used by hospitals to code diagnoses before 1999, when the Australian modification of the 10th revision (ICD-10-AM)¹⁶ was introduced in WA. All ICD-10-AM codes were converted into the best match ICD-9-CM codes using a backwards conversion table.¹⁷ ICD-9-CM codes were grouped into 12 diagnostic categories (Appendix 1, online only). Categories were designed to group all infectious codes together and were modified from previous work.^{18,19} The codes for different infections were further grouped into infectious diagnostic categories (Appendix 2, online only). In WA hospitals, up to 20 diagnoses can be recorded in addition to a principal diagnosis, while operative procedures are coded separately. Unless otherwise stated, we used the principal diagnosis for analysis, as this represents the primary reason for admission. Transfers between hospitals were identified as a single admission when a child was readmitted within 24 hours of discharge with the same principal diagnosis code. Otherwise, each hospitalization was treated as a separate admission. A birth in hospital per se generates an admission record, but a birth record was only included as a hospitalization when there was a principal diagnosis code that indicated an illness. Pneumococcal vaccines were not available for children in WA during the study period.

Statistical Methods. For all admissions and for different disease categories, we calculated the proportion of live-born children who were hospitalized at least once and the admission rate per 1000 live births (which may include multiple admissions for individual children). To analyze trends of admission rates over time, only admissions from 1992 to 2000 were included as those years contained the whole unbiased population of children from birth to age 2 years. Relative rates and relative proportions were calculated for Aboriginal compared with non-Aboriginal groups. To ac-

count for nonindependence of repeat admissions, linear time trends were calculated by negative binomial regression. All comparisons were statistically significant below a probability of 10^{-3} unless otherwise stated. Analyses were performed using SPSS version 11.5 (SPSS Inc., Chicago) and STATA version 9 (Stata Corporation, College Station, TX).

Use of these data was approved by the WA Health Department Confidentiality of Health Information Committee and the University of Western Australia Human Research Ethics Committee.

RESULTS

Admissions to Hospital. There were 270,068 live births from 1990 to 2000, of whom 6.4% (17,366) were Aboriginal and 51% (138,686) were male. Almost three fourths (74.0%) of non-Aboriginal children were resident in the metropolitan area and only 8.4% in remote areas, while 33.6% of Aboriginal children lived in the metropolitan area and 45.8% in remote areas. Overall 49% of the birth cohort (133,410 live births) were admitted to the hospital at least once in the first 2 years of life, and infection was the most common reason for admission (34% of all admissions, Table 1, available online only). Hospitalizations at birth for illness ($n = 61,173$ of 235,104 total admissions) were predominately for perinatal conditions (71%) or congenital abnormalities (10%), but 13% had a principal diagnosis of infection. Approximately one third of children were hospitalized at least once during the neonatal period (36.5% of Aboriginal children and 31.6% of non-Aboriginal children), and infection was one of the 4 leading causes of admission (Fig. 1A). After the neonatal period, 58.7% of Aboriginal children and 26.5% of non-Aboriginal children were admitted at least once and infection was by far the predominant cause (Fig. 1B). Findings were essentially unchanged when premature babies were excluded from analyses.

Admissions to Hospital With Infection. One in 5 non-Aboriginal children (18.4%, $n = 46,613$) and half the Aboriginal children (49.0%, $n = 8517$) were hospitalized at least once before the age of 2 years for an infection. Admission rates changed significantly over time (Fig. 2). In non-Aboriginal children, the admission rates for both infectious and noninfectious diseases rose significantly (by an average of 3.7% and 3.9% annually, $P < 0.001$), but the rises were not significantly different from each other ($P = 0.78$). In contrast, admission rates for Aboriginal children fell significantly by an average of 4.4% annually for infections, and by only 1.3% annually for noninfectious diseases ($P < 0.001$ for both, but also significantly different from each other, $P < 0.001$). As a result of these divergent trends, the admission rate for infections in Aboriginal children was 5.8 times greater than in non-Aboriginal children in 1992; but by the year 2000, the ratio had declined to 3.3. Aboriginal children were 6.6 times more likely than non-Aboriginal children to be admitted more than once for an infection, the differential increasing to 13 times when considering admission with an infection on 3 or more occasions (14.3%, $n = 2487$, of Aboriginal children compared with 1.1%, $n = 2829$, of non-Aboriginal children admitted 3 or more times for infection).

FIGURE 1. Hospital admission rates/mo/1000 live births for different disease categories (A) before age 29 days and (B) aged 29 days to <2 years among Aboriginal and non-Aboriginal children born in Western Australia 1990 to 2000. Note that perinatal conditions are not shown in A: rates were 255 per 1000 live Aboriginal births and 224 per 1000 live non-Aboriginal births (Table 1, available online).

FIGURE 2. Admission rates per 1000 live births under age 2 years for infections and for all noninfectious diseases in Aboriginal and non-Aboriginal children, 1992 to 2000.

For all children, admission rates for infection were higher in rural and remote areas than in the metropolitan area. Among Aboriginal children, the rates were 705 per 1000 live births in the capital, 1217 per 1000 live births in rural areas

and 1366 per 1000 live births in remote areas. These rates were, respectively, 3.4 (95% confidence interval [CI] 3.3–3.5), 4.0 (95% CI 3.8–4.1) and 5.3 (95% CI 5.1–5.4) times higher than in non-Aboriginal children from the equivalent

TABLE 2. Hospital Admissions for Infection in the first 2 Years of Life for Aboriginal and Non-Aboriginal Children Born in Western Australia 1990-2000

Infectious Illness	Aboriginal				Non-Aboriginal				RR (95% CI)
	Children (% of live births)	Admissions	Rate*	Median Age (mo)	Children (% of live births)	Admissions	Rate*	Median Age (mo)	
Upper respiratory tract infections									
Otitis media	952 (5.5)	1159	66	13	7634 (3.0)	8372	33	16	2.0 (1.9, 2.1)
Other	1932 (11.1)	2436	140	9	8553 (3.4)	9572	38	13	3.7 (3.5, 3.9)
Lower respiratory tract infections									
Bronchiolitis	2218 (12.8)	3197	184	6	7057 (2.8)	8079	32	5	5.8 (5.5, 6.0)
Pneumonia	1631 (9.4)	2177	125	12	2191 (0.9)	2341	9	14	13.5 (12.8, 14.3)
Bronchitis	324 (1.9)	355	20	10	592 (0.2)	604	2	10	8.6 (7.5, 9.8)
Influenza	107 (0.6)	110	6	9	399 (0.2)	410	2	9	3.9 (3.2, 4.8)
Nonrespiratory infections									
Gastroenteritis	3232 (18.6)	4559	262	11	7421 (2.9)	8049	32	13	8.2 (7.9, 8.5)
Perinatal infections	392 (2.3)	394	23	0	4294 (1.7)	4306	17	0	1.3 (1.2, 1.5)
Neonatal conjunctivitis	95 (0.5)	95	5	0	4212 (1.7)	4222	16	0	0.3 (0.3, 0.4)
Urinary tract infection	372 (2.1)	434	24	10	1494 (0.6)	1649	7	6	3.8 (3.4, 4.3)
Skin infections	803 (4.6)	907	52	11	1040 (0.4)	1093	4	11	12.1 (11.1, 13.2)
Scabies	841 (4.8)	1167	67	5	28 (0.0)	32	0	10	530.7 (373.5, 754.0)
Septicemia	110 (0.6)	113	6	9	430 (0.2)	440	2	10	3.7 (3.0, 4.6)
Meningitis	115 (0.7)	125	7	5	317 (0.1)	328	1	5	5.5 (4.5, 6.8)
Viral and Chlamydial	604 (3.5)	639	37	10	4233 (1.7)	4433	18	11	2.1 (1.9, 2.3)
Convulsions	257 (1.5)	326	19	13	3005 (1.2)	3512	14	15	1.4 (1.2, 1.5)
Other†	1025 (5.9)	1152	66	9	3534 (1.4)	3813	15	10	4.4 (4.1, 4.7)
Total	8517 (49.0)	19,345	1114	9	46,613 (18.4)	61,255	242	10	4.6 (4.5, 4.7)

Note. Children can be represented in >1 category (multiple cause coding).

*Number of admissions in the first 2 years of life/1000 live births.

†The top 3 diagnoses in "Other" were fever (39%), other convulsions and fits (12%) and whooping cough (9%).

RR indicates ratio of Aboriginal to non-Aboriginal rates; CI, confidence interval.

geographic areas (230 per 1000, 282 per 1000 and 266 per 1000 live births in metropolitan, rural and remote areas, respectively). All boys had a significantly higher admission rate for infectious diseases (336 per 1000 live births) than girls (259 per 1000 live births).

Predominant causes of admissions with infection were respiratory tract infections (48%) and gastrointestinal infections (16%) (Table 2). Admission rates for all categories of infections were higher in Aboriginal than non-Aboriginal children, except for neonatal conjunctivitis. Marked disparity was seen for scabies infestations (admission rate 531 times higher), pneumonia (14 times), skin infections (12 times), bronchitis (9 times), gastrointestinal infections (8 times), meningitis and bronchiolitis (6 times). The median age of admission was generally lower for Aboriginal than non-Aboriginal children (Table 2).

When we considered infections recorded either as the principal diagnosis or as a secondary diagnosis, the most marked increases in admission rates (compared with principal diagnosis only) were in Aboriginal children in whom comorbidities of otitis media, urinary tract infection, neonatal conjunctivitis and skin infections were more likely to be recorded than in non-Aboriginal children (data not shown).

The mean length of stay in hospital for an infection was 5 days for an Aboriginal child and 3 days for a non-Aboriginal child. Meningitis was responsible for the longest average duration of stay in hospital (9.2 days), while bronchiolitis and

gastrointestinal infections accounted for more total days spent in hospital by the entire cohort of children than other infectious illnesses (bronchiolitis: Aboriginal 13,883 days, non-Aboriginal 27,622 days; gastrointestinal infections: Aboriginal 24,383 days, non-Aboriginal 17,734 days).

There were 19 Aboriginal children and 37 non-Aboriginal children who were admitted with an infection who died in hospital. There were 11 deaths out of 553 admissions with a diagnosis of septicemia (2.0%), 8 of 453 meningitis admissions (1.8%), 10 of 4853 pneumonia admissions (0.2%) and 9 of 11,276 bronchiolitis admissions (0.1%).

DISCUSSION

To our knowledge, this is the most extensive study of hospital admissions in indigenous and nonindigenous children. The great strength of this study is that we have 10 years of linked demographic and hospital morbidity data, with reliable ascertainment of indigenous status,¹² on a large stable total population. We have found that overall almost half of all children are admitted to hospital in the first 2 years of life (more than one fourth beyond the neonatal period), and we highlight the continuing burden of infectious diseases as the main cause of hospitalization in young children, far outstripping other diagnostic categories beyond the neonatal period. In non-Aboriginal children, hospitalization rates for infectious illnesses have actually increased. In contrast, admission

rates for infections in Aboriginal children have declined, but the disproportionate burden of disease in Aboriginal children remains, particularly in rural and remote areas. Compared with non-Aboriginal children, Aboriginal children suffer more frequent admissions and comorbidities, stay in hospital longer and are at greater risk of death in hospital despite accessing hospital care. While gastroenteritis and respiratory infections, particularly upper respiratory tract infections and bronchiolitis, are responsible for most infectious admissions, the greatest differences between Aboriginal and non-Aboriginal children were seen for scabies, skin infections and pneumonia.

The quality of routinely collected administrative data, particularly for completeness and accuracy of diagnosis, must be considered. WADLS data quality is generally good. In 2001, the database included 2.3 million links, of which 98% were successfully joined.²⁰ Validation exercises have been undertaken to ensure quality of routinely collected data.^{9,11,12} Missing data are very sparse. There are 21 different quality checks built into the provision of data from hospitals and periodic audits of random selections of hospital-assigned codes.^{11,21} However, primary care contact data are currently not included in the WADLS. Thus, we can only speculate that differences in access to primary health care or changes in referral practices of primary healthcare providers account for some of the temporal and geographic variability in admission rates.

We have only identified one comparable study from the United States, which was not based on a total population and included morbidity only before the age of 12 months.⁵ When investigating hospitalizations between 1988 and 1999, the authors also found a predominance of infectious disease, a higher infectious disease burden in boys than girls and in American Indian and Alaska Native (AI/AN) infants compared with the general U.S. infant population.⁵ They too noted a decline in infection admission rates in the AI/AN children and an increase in the general U.S. population. A decline in gastroenteritis admissions for the AI/AN population of the United States was also described by this group; however, rotavirus and respiratory syncytial virus remain important causes of infectious disease morbidity in these populations.^{22–24} An earlier study of children born in WA in 1986 found lower overall admission rates for non-Aboriginal children and higher rates for Aboriginal children than we have described here.⁶ In Aboriginal children, admission rates for pneumonia, bronchiolitis and bronchitis have declined from 425 per 1000 live births in 1986 to 329 per 1000 live births in our study, while equivalent rates increased in non-Aboriginal children from 33 per 1000 to 43 per 1000 live births.²⁵ This is in line with the trend of increasing admissions of non-Aboriginal children and decreasing admissions of Aboriginal children during our study.

Changes in availability of services at the primary healthcare level, shifts in diagnostic practices and real changes in disease incidence are all likely to have contributed to the temporal changes in admission rates described here. Changes in admission rates are unlikely to be due to changes in identification of indigenous status, as this has not altered substantially in the decade under study.²⁶ The decline in

infectious admissions among Aboriginal children must, in part, represent improvements in health of Aboriginal children, with a marked fall in admissions for gastrointestinal infections over the last 3 decades⁸ as well as invasive *Haemophilus influenzae* type b (Hib) disease following introduction of conjugate Hib vaccine in 1993.²⁷

The increase in admissions in non-Aboriginal children may be the result of one or more of the following: an increasing proportion of children surviving extreme prematurity or suffering chronic medical conditions, increasing use of day care (a known risk factor for respiratory and gastrointestinal infections) and changes in pattern of presentation to emergency departments and admission policies that have accompanied the decline in bulk billing (no fee for service) in general practice in Australia.²⁸ Changes in bulk billing practices would not have affected Aboriginal children to the same extent, in part because they continue to have access to free medical care through Aboriginal Medical Services. Furthermore, many Aboriginal people have limited direct access to hospital services due to lack of transport and the long distances that they have to travel to the nearest hospital, posing challenges in providing appropriate and equitable services throughout the state. A shift in recent years from a diagnosis of asthma to bronchiolitis in young children has been described elsewhere^{29,30} and may have contributed to the rise in admissions for infections in non-Aboriginal children, but cannot explain observed trends in Aboriginal children.^{30a}

Reductions in burden of Hib and pneumococcal diseases following the introduction of vaccination programs^{31–35} show that substantial reductions in the burden of infectious disease, and in health disparity, can be achieved given government commitment to implement preventive measures. The continuing burden of infectious diseases emphasizes the urgent need for safe, efficacious respiratory syncytial virus and rotavirus vaccines^{36,37} and implementation of a childhood influenza immunization program.³⁸

Aboriginal children are at high risk of multiple admissions and dying in hospital. These findings may reflect poorer general health and/or nutrition, poor access to health services or delayed treatment-seeking behavior. Not only do hospital staff need to develop appropriate strategies to manage this high-risk group once admitted, but improvements in economic disparity, living conditions and primary care are required to reduce hospitalization rates and improve outcomes. Importantly, more than one third of deaths from infectious diseases in Aboriginal infants in WA actually occur outside hospital, supporting the need for improvement at the primary healthcare level.⁴ Solutions are not only biomedical: governments must work with indigenous communities to improve infrastructure (housing, management, economic, social and human³⁹), train indigenous health staff and support cultural education of healthcare providers.⁴⁰ Interventions in remote communities have failed when infrastructure is only partially improved and mobility of the population is not addressed.⁴¹ More distal factors on the complex pathways to poor indigenous health, such as social disadvantage, racism and dispossession, must also be addressed.^{42,43}

The data presented here provide the necessary baseline for further investigations needed to develop appropriate in-

terventions. Linked data, as in the WADLS, offer a unique opportunity to investigate causal pathways to infectious diseases and their consequences, including intellectual disability, educational achievement and judicial outcomes. Linkage to databases relevant to primary health care will help identify barriers to provision of optimal primary care and access to tertiary facilities. Linkage to laboratory data will enable accurate pathogen-specific analysis of hospital admissions.

These data provide a comprehensive evidence base for the development and evaluation of health policies and public health interventions. To reduce early childhood morbidity, mortality and healthcare costs, there is clearly a need to continue to focus on interventions aimed at reducing the burden of infectious diseases, with a particular emphasis on indigenous child health.

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