Effect of socioeconomic disadvantage, remoteness and Indigenous status on hospital usage for Western Australian preterm infants under 12 months of age: a population-based data linkage study

Natalie A Strobel,1 Sue Peter,2 Kimberley E McAuley,1 Daniel R McAullay,1,3 Rhonda Marriott,4 Karen M Edmond1

ABSTRACT

Objectives: Our primary objective was to determine the incidence of hospital admission and emergency department presentation in Indigenous and non-Indigenous preterm infants aged postdischarge from birth admission to 11 months in Western Australia. Secondary objectives were to assess incidence in the poorest infants from remote areas and to determine the primary causes of hospital usage in preterm infants.

Design: Prospective population-based linked data set.

Setting and participants: All preterm babies born in Western Australia during 2010 and 2011.

Main outcome measures: All-cause hospitalisations and emergency department presentations.

Results: There were 6.9% (4211/61 254) preterm infants, 13.1% (433/3311) Indigenous preterm infants and 6.5% (3778/57 943) non-Indigenous preterm infants born in Western Australia. Indigenous preterm infants had a higher incidence of hospital admission (adjusted incident rate ratio (aIRR) 1.24, 95% CI 1.08 to 1.42) and emergency department presentation (aIRR 1.71, 95% CI 1.44 to 2.02) compared with non-Indigenous preterm infants. The most disadvantaged preterm infants (7.8/1000 person days) had a greater incidence of emergency presentation compared with the most advantaged infants (3.1/1000 person days) (aIRR 1.61, 95% CI 1.30 to 2.00). The most remote preterm infants (7.8/1000 person days) had a greater incidence of emergency presentation compared with the least remote preterm infants (3.0/1000 person days; aIRR 1.82, 95% CI 1.49 to 2.22).

Conclusions: In Western Australia, preterm infants have high hospital usage in their first year of life. Infants living in disadvantaged areas, remote area infants and Indigenous infants are at increased risk. Our data highlight the need for improved postdischarge care for preterm infants.

INTRODUCTION

In 2010, it was estimated globally that 15 million babies, 11.1% of all live births worldwide, were born preterm (<37 weeks gestation).1 Preterm infants are at a greater risk of experiencing serious health complications than full-term infants. Complications include respiratory infections, anaemia, vision and hearing loss, and developmental delay.1 Infants with complications from prematurity need many more health and social services than full-term infants and infants without these complications.2 3 This places a high economic, health and social burden on families and health systems.4

In 2013, 8.6% of all babies born in Australia were preterm, most with a gestational age of between 32 and 36 completed weeks.5 These data are similar to other developed countries. However, during 2013, 14% of babies born to Australian Aboriginal and Torres Strait Islander (hereafter referred to as Indigenous) mothers were preterm.6 This high preterm risk has changed little over the past decade.6 These data are comparable to...
many of the poorest countries in the world where the most recent data indicate that ~12% of babies are born preterm.7

Despite the high risks, there has been little focus on understanding hospital usage patterns and what follow-up care is needed for high-risk preterm Aboriginal infants, especially the poorest infants who live in remote areas. This is particularly important because mothers who carry a higher burden of ill health and social dysfunction have a higher risk of delivering a preterm or low birthweight infant.8 9 These mothers often have more difficulties accessing the health system and adhering to medication regimens.8 9

Western Australia (WA) has a large de-identified prospective longitudinal population-based data system involving the probabilistic systematic record linkage of total population administrative health data sets.10 Data are available for birth cohorts and include information on maternal and infant characteristics, hospital admission and emergency department presentations including length of stay, cause of hospital admission, Indigenous status and socioeconomic status.

Our study was designed to assess differentials in incidence of all-cause hospital admission and emergency department presentation for Indigenous and non-Indigenous preterm infants (born <37 weeks) during their first 12 months of life. Our primary objective was to determine the incidence of hospital admission and emergency department presentation in Indigenous and non-Indigenous infants from time of discharge from birth admission to 11 months (0–11 months). Secondary objectives were to assess incidence in the poorest infants from remote areas and to determine the primary causes of hospital usage in preterm infants.

METHODS

Study setting and database access

All live births occurring at <37 weeks gestational age in WA from 1 January 2010 to 31 December 2011 were included in this study. Prospective population-based linked data from the WA Midwives’ Notification System, Hospital Morbidity Data System, Emergency Department Data Collection, Death Registrations, the Index of Relative Socio-Economic Disadvantage (IRSD)11 and the Accessibility/Remoteness Index of Australia (ARIA)12 were obtained from the Department of Health of Western Australia (DOHWA).

The Midwives’ Notification System includes clinical (infant weight, gestational age, Apgar score, multiple birth, gravidity) and sociodemographic (baby’s gender, mother’s age, Indigenous status, socioeconomic status, remoteness index) data on all WA live births and stillbirths of more than 20 weeks’ gestation or birth weight >400 g which are reported by trained midwives within 48 hours of delivery. The Hospital Morbidity Data System and Emergency Department Data Collection include data on all completed hospital admissions and emergency department presentations to all public hospitals in WA. These data are entered by trained medical records staff following the occasion of service. Death Registrations are linked monthly and include date and cause of death. The Australian Bureau of Statistics (ABS) IRSD divides statistical local areas based on the 2006 Australian national census data into quintiles from most deprived (1) to least deprived (5).11 The ARIA was developed by the Department of Health and Aged Care and is maintained by the Australian Institute of Health and Welfare (AIHW).12 This index classifies geographic location on the basis of isolation and distance from service centres and healthcare facilities. ARIA data are split into five categories from least remote (1; major cities) to most remote (5; remote area communities).

The databases were systematically linked by DOHWA data linkage staff using probabilistic matching and de-identified. The final database included date of hospital admission, date of emergency department presentation, hospital length of stay, maternal ethnicity, maternal age, gravidity, infant age, infant birth weight, gestational age, infant sex, multiple birth and infant health status at birth (Apgar score). ISRD quintile, ARIA level and health region from the Midwives’ Notification System were also included.

Inclusion and exclusion criteria

Infants were classified as Indigenous if the mother was recorded in the Midwives’ Notification System as an Aboriginal and/or Torres Strait Islander.13 All other infants were classified as non-Indigenous. To avoid clustering within multiple births, the population was limited to singleton babies.

Definitions

Specific cut points were used to define preterm; ‘extremely preterm’ (<28 weeks gestation); ‘very preterm’ (births between 28 and <32 weeks gestation); and ‘moderate preterm’ (births between 32 and <37 weeks gestation).1 The small for gestational age index was calculated as small for gestational age ‘SGA’ (<10th centile for weight); appropriate for gestational age ‘AGA’ (10–90th centile for weight); large for gestational age ‘LGA’ (>90th centile).14

We defined the ‘person time at risk’ as the number of days between discharge from the birth admission to 11 months of chronological age. This excluded the stay in hospital after birth for both well and unwell babies. Hospital admissions were defined as the number of admissions of infants to a WA hospital ward for care during the period between discharge from the birth admission to 11 months. Between hospital transfers were included as one admission. Emergency department presentations were defined as the number of presentations of infants to a WA hospital emergency department (regardless of whether the child was admitted) during the period between discharge from the birth admission...
RESULTS

During 2010–2011 in WA there were 62,965 live births; 98.5% (61,254) were singletons and 6.9% (4211) of these infants were preterm. Of these, 2.0% (84/4211) preterm infants died in the first year of life (web appendix A). In total, 13.1% (433/3311) of the preterm infants were classified as Indigenous and 6.5% (3778/57,943) were classified as non-Indigenous (table 1). In total, 37.2% (161) of preterm Indigenous infants were classified in the most disadvantaged quintile compared with 3.5% (132) non-Indigenous infants. In total, 38.6% (167) of preterm Indigenous infants lived in the most remote area (ARIA 5) compared with 3.6% (134) of non-Indigenous infants (table 1).

The median (IQR) length of stay during the birth admission was 75 days (IQR 4–107) for infants with gestational age <28 weeks; 33 days (IQR 21–48) for infants with gestational age 28 to <32 weeks and 33 days (IQR 21–31) for infants with gestational age 32 to 36 weeks (IQR 21–37). Web appendix A provides further detail of the length of hospital stay in birth hospital.

Overall, there were a total 5284 hospital admissions in 3102 preterm infants and 5657 emergency presentations in 2220 preterm infants during the period between discharge from birth admission to 11 months of chronological age. Of the hospital admissions, 2233 (42.3%) were elective admissions, 3007 (56.9%) were emergency-related admissions and the remaining 44 (0.8%) were unknown. In total, 73.7% (3102) of preterm infants had at least one hospital admission and 52.7% (2220) of infants had at least one emergency department presentation between discharge from birth admission to 11 months (web appendix B).

Indigenous preterm infants had a higher incidence of emergency department presentation (aIRR 1.71, 95% CI 1.44 to 2.02) and hospital admission (aIRR 1.24, 95% CI 1.08 to 1.42) compared with non-Indigenous preterm infants even after adjusting for confounding factors (table 2). Preterm infants with gestational age under 32 weeks had a greater incidence of hospital admission (5.9/1000 person days) compared with infants with a gestational age 32–37 weeks (3.3/1000 person days; aIRR 1.79, 95% CI 1.67 to 1.93; table 2). There was also an increased incidence of emergency department presentations for infants with a gestational age under 32 weeks (aIRR 1.40, 95% CI 1.27 to 1.54). Length of stay for birth admissions over 28 days was significantly associated with subsequent hospital admissions (aIRR 1.98, 95% CI 1.81 to 2.17) and emergency
department presentations (aIRR 1.66, 95% CI 1.48 to 1.86) compared with stays <14 days (web appendix C). There were no marked effects of other sociodemographic characteristics on hospital usage in preterm infants (table 2).

Preterm infants living in the most disadvantaged areas had an increased incidence of presenting to the emergency department (7.8/1000 person days) compared with the most advantaged (ISRD 5) preterm infants (3.1/1000 person days; aIRR 1.61, 95% CI 1.30

| Characteristics | Total number of infants n=4211 | Number of Indigenous infants n=433 | Number of non-Indigenous infants n=3778 | OR 95% CI | p Value |
|----------------|---------------------------------|------------------------------------|------------------------------------------|----------|---------|
| Infant Prematurity (week) | | | | | |
| <28 | 186 (4.4%) | 28 (6.5%) | 158 (4.2%) | 1.58 (1.05 to 2.40) | 0.030 |
| 28<32 | 311 (7.4%) | 45 (10.4%) | 266 (7.0%) | 1.53 (1.10 to 2.14) | 0.012 |
| 32<37 | 3714 (88.2%) | 360 (83.1%) | 3354 (88.8%) | 0.62 (0.48 to 0.82) | 0.001 |
| Child sex | | | | | |
| Male | 2316 (55.0%) | 226 (52.2%) | 2090 (55.3%) | 0.88 (0.72 to 1.08) | 0.216 |
| Female | 1895 (45.0%) | 207 (47.8%) | 1688 (44.7%) | 1.13 (0.93 to 1.38) | 0.216 |
| Birth weight Low birth weight (<2500 g) | 1983 (47.1%) | 258 (59.6%) | 1725 (45.7%) | 0.57 (0.47 to 0.70) | <0.001 |
| Normal birth weight (≥2500 g) | 2228 (52.9%) | 175 (40.4%) | 2053 (54.3%) | 1.75 (1.43 to 2.15) | <0.001 |
| Small for gestational age index SGA (<10th centile) | 335 (8.0%) | 48 (11.1%) | 287 (7.6%) | 1.52 (1.10 to 2.10) | 0.011 |
| AGA (10th–90th centile) | 3386 (80.4%) | 341 (78.8%) | 3045 (80.6%) | 0.91 (0.71 to 1.16) | 0.431 |
| LGA (>90th centile) | 483 (11.5%) | 42 (9.7%) | 441 (11.7%) | 0.82 (0.58 to 1.14) | 0.231 |
| Data missing | NP | NP | NP | | |
| APGAR 5 score <7 (abnormal) | 259 (6.2%) | 31 (5.1%) | 228 (6.0%) | 1.20 (0.81 to 1.76) | 0.369 |
| ≥7 (healthy) | 3951 (93.8%) | 402 (94.9%) | 3549 (93.9%) | 0.83 (0.56 to 1.23) | 0.357 |
| Data missing | NP | NP | NP | | |
| Maternal age (years) <20 | 243 (5.8%) | 87 (18.4%) | 156 (4.1%) | 5.84 (4.39 to 7.76) | <0.001 |
| 20–24s | 671 (15.9%) | 135 (31.6%) | 536 (14.2%) | 2.74 (2.19 to 3.42) | <0.001 |
| 25–29 | 1115 (26.5%) | 109 (27.3%) | 1006 (26.6%) | 0.93 (0.74 to 1.17) | 0.516 |
| 30–34 | 1207 (28.7%) | 57 (12.9%) | 1150 (30.4%) | 0.35 (0.26 to 0.46) | <0.001 |
| 35+ | 975 (23.2%) | 46 (9.8%) | 930 (24.6%) | 0.36 (0.26 to 0.49) | <0.001 |
| Gravidity 0 | 1358 (32.2%) | 95 (21.9%) | 1263 (33.4%) | 0.56 (0.44 to 0.71) | <0.001 |
| 1 | 1121 (26.6%) | 90 (20.8%) | 1031 (27.3%) | 0.70 (0.55 to 0.89) | <0.001 |
| 2 | 736 (17.5%) | 65 (15.0%) | 671 (17.8%) | 0.82 (0.62 to 1.08) | 0.154 |
| ≥3 | 996 (23.7%) | 183 (42.3%) | 813 (21.5%) | 2.67 (2.17 to 3.28) | <0.001 |
| Area Socioeconomic status Most disadvantaged 1 | 293 (7.0%) | 161 (37.2%) | 132 (3.5%) | 17.09 (13.13 to 22.22) | <0.001 |
| 2 | 646 (15.3%) | 58 (13.4%) | 588 (15.6%) | 0.86 (0.64 to 1.15) | 0.299 |
| 3 | 537 (12.8%) | 56 (12.9%) | 481 (12.7%) | 1.04 (0.77 to 1.40) | 0.793 |
| 4 | 1143 (27.1%) | 75 (17.3%) | 1068 (28.3%) | 0.54 (0.42 to 0.70) | <0.001 |
| Least disadvantaged 5 | 1486 (35.3%) | 65 (15.0%) | 1421 (37.6%) | 0.30 (0.23 to 0.39) | <0.001 |
| Data missing | 106 (2.5%) | 18 (4.2%) | 88 (2.3%) | | |
| Geographic location Major city | 1802 (42.8%) | 84 (19.4%) | 1718 (45.5%) | 0.29 (0.23 to 0.37) | <0.001 |
| Inner regional | 1559 (37.0%) | 82 (18.9%) | 1477 (39.1%) | 0.37 (0.29 to 0.47) | <0.001 |
| Outer regional | 327 (7.8%) | 58 (13.4%) | 269 (7.1%) | 2.07 (1.52 to 2.80) | <0.001 |
| Remote | 116 (2.8%) | 24 (5.5%) | 92 (2.4%) | 2.40 (1.51 to 3.81) | <0.001 |
| Very remote | 301 (7.1%) | 167 (38.6%) | 134 (3.6%) | 17.87 (13.76 to 23.20) | <0.001 |
| Data missing | 106 (2.5%) | 18 (4.2%) | 88 (2.3%) | | |

AGA, appropriate for gestational age; LGA, large for gestational age; NP, not publishable due to small numbers and confidentiality restrictions; SGA, small for gestational age.
| Characteristics | Events | Time at risk | (Events/risk)×1000 | Unadjusted IRR (95% CI) | p Value | aIRR (95% CI)* | p Value |
|-----------------|--------|--------------|---------------------|-------------------------|---------|----------------|---------|
| **All-cause hospitalisations postdischarge from birth admission to 11 months** | | | | | | | |
| **Infant** | | | | | | | |
| Indigenous status | 745 | 152 285 | 4.89 | 1.44 (1.28 to 1.62) | <0.001 | 1.24 (1.08 to 1.42) | 0.002 |
| Non-Indigenous | 4539 | 1 335 534 | 3.40 | 1.00 | | 1.00 | |
| Prematurity† (week) | | | | | | | |
| <28 | 340 | 54 951 | 6.19 | 1.95 (1.74 to 2.19) | <0.001 | 1.91 (1.70 to 2.13) | <0.001 |
| 28<32 | 598 | 103 070 | 5.80 | 1.76 (1.61 to 1.93) | <0.001 | 1.73 (1.59 to 1.88) | <0.001 |
| 32<37 | 4346 | 1 329 798 | 3.27 | 1.00 | | 1.00 | |
| Child sex | | | | | | | |
| Male | 3036 | 818 577 | 3.71 | 1.10 (1.04 to 1.17) | 0.002 | 1.16 (1.09 to 1.24) | <0.001 |
| Female | 2248 | 669 242 | 3.36 | 1.00 | | 1.00 | |
| Birth weight | | | | | | | |
| Low birth weight (<2500 g) | 3212 | 685 424 | 4.69 | 1.84 (1.72 to 1.96) | <0.001 | 1.83 (1.72 to 1.96) | <0.001 |
| Normal birth weight (≥2500 g) | 2072 | 802 395 | 2.58 | 1.00 | | 1.00 | |
| SGA index | | | | | | | |
| SGA (<10th centile) | 576 | 116 067 | 4.96 | 1.42 (1.26 to 1.59) | <0.001 | 1.41 (1.26 to 1.58) | <0.001 |
| AGA (10th–90th centile) | 4226 | 1 196 920 | 3.53 | 1.00 | | 1.00 | |
| LGA (>90th centile) | 482 | 172 420 | 2.80 | 0.79 (0.72 to 0.86) | <0.001 | 0.78 (1.26 to 1.58) | <0.001 |
| APGAR 5 score | | | | | | | |
| <7 (abnormal) | 396 | 87 068 | 4.55 | 1.33 (1.18 to 1.50) | <0.001 | 0.94 (0.83 to 1.06) | 0.322 |
| ≥7 (healthy) | 4885 | 1 400 390 | 3.49 | 1.00 | | 1.00 | |
| Maternal | | | | | | | |
| Maternal age (years) | | | | | | | |
| <20 | 372 | 86 080 | 4.32 | 1.22 (1.06 to 1.42) | 0.007 | 1.15 (0.99 to 1.34) | 0.060 |
| 20–24 | 853 | 237 825 | 3.59 | 1.02 (0.93 to 1.13) | 0.564 | 0.98 (0.88 to 1.08) | 0.633 |
| 25–29 | 1378 | 393 858 | 3.50 | 1.00 | | 1.00 | |
| 30–34 | 1459 | 427 127 | 3.42 | 0.98 (0.90 to 1.07) | 0.704 | 1.00 (0.92 to 1.09) | 0.987 |
| 35+ | 1222 | 342 921 | 3.56 | 1.03 (0.95 to 1.12) | 0.444 | 0.99 (0.91 to 1.08) | 0.865 |
| Gravidity | | | | | | | |
| 0 | 1658 | 479 189 | 3.46 | 0.98 (0.90 to 1.06) | 0.572 | 0.89 (0.82 to 0.97) | 0.009 |
| 1 | 1323 | 396 837 | 3.33 | 0.94 (0.86 to 1.03) | 0.186 | 0.91 (0.83 to 0.99) | 0.039 |
| 2 | 924 | 261 034 | 3.54 | 1.00 | | 1.00 | |
| ≥3 | 1379 | 350 759 | 3.93 | 1.12 (1.01 to 1.24) | 0.033 | 1.02 (0.92 to 1.12) | 0.770 |
| Geographic location | | | | | | | |
| Major city | 2089 | 635 695 | 3.29 | 1.00 | | 1.00 | |
| Inner regional | 1982 | 552 517 | 3.59 | 1.09 (1.02 to 1.17) | 0.012 | 1.07 (1.01 to 1.14) | 0.017 |
| Outer regional | 507 | 115 243 | 4.40 | 1.34 (1.18 to 1.52) | <0.001 | 1.24 (1.09 to 1.41) | 0.001 |
| Remote | 128 | 40 877 | 3.13 | 0.95 (0.80 to 1.13) | 0.569 | 0.95 (0.81 to 1.13) | 0.574 |
| Very remote | 439 | 106 142 | 4.14 | 1.27 (1.05 to 1.54) | 0.014 | 1.09 (0.92 to 1.29) | 0.330 |

**All-cause emergency department presentations postdischarge from birth admission to 11 months**

| Characteristics | Events | Time at risk | (Events/risk)×1000 | Unadjusted IRR (95% CI) | p Value | aIRR (95% CI)* | p Value |
|-----------------|--------|--------------|---------------------|-------------------------|---------|----------------|---------|
| **Infant** | | | | | | | |
| Indigenous status | 1257 | 152 285 | 8.25 | 2.20 (1.94 to 2.49) | <0.001 | 1.71 (1.44 to 2.02) | <0.001 |
| Non-Indigenous | 4400 | 1 335 534 | 3.29 | 1.00 | | 1.00 | |

*Continued*
to 2.00; table 2). There also appeared to be some evidence of a dose–response with increased incidence of emergency department presentation with increased levels of disadvantage for Indigenous infants (p value for trend=0.004; table 3) but not for infants overall (p value for trend=0.615) and for non-Indigenous preterm infants (p value for trend=0.178; tables 2 and 3). Preterm infants living in the most disadvantaged areas had a higher but not significant incidence of hospital admissions (4.5/1000 person days) compared with the most advantaged infants (3.4/1000 person days; aIRR 1.11, 95% CI 0.95 to 1.30). There was no obvious trend (p value for trend=0.800; tables 2 and 3).

| Characteristics               | Events | Time at risk (Events/risk)×1000 | Unadjusted IRR (95% CI) | p Value | aIRR (95% CI)* | p Value |
|-------------------------------|--------|---------------------------------|-------------------------|---------|----------------|---------|
| Prematurity† (week)           |        |                                 |                         |         |                |         |
| <28                           | 295    | 54 951 5.37                     | 1.47 (1.23 to 1.76)     | <0.001  | 1.48 (1.25 to 1.76) | <0.001 |
| 28–32                         | 526    | 103 070 5.10                    | 1.36 (1.21 to 1.52)     | <0.001  | 1.36 (0.21 to 1.53) | <0.001 |
| 32–37                         | 4836   | 1 329 798 3.64                  | 1.00                    |         | 1.00           |         |
| Child sex                     |        |                                 |                         |         |                |         |
| Male                          | 3327   | 818 577 4.06                    | 1.16 (1.09 to 1.25)     | <0.001  | 1.20 (1.11 to 1.29) | <0.001 |
| Female                        | 2330   | 669 242 3.48                    | 1.00                    |         | 1.00           |         |
| Birth weight                  |        |                                 |                         |         |                |         |
| Low birth weight (<2500 g)    | 2821   | 685 423 4.12                    | 1.18 (1.09 to 1.27)     | <0.001  | 1.16 (1.06 to 1.26) | 0.001  |
| Normal birth weight (≥2500 g) | 2836   | 802 395 3.53                    | 1.00                    |         | 1.00           |         |
| SGA index                     |        |                                 |                         |         |                |         |
| SGA (<10th centile)           | 523    | 116 067 4.51                    | 1.19 (1.03 to 1.39)     | 0.020   | 1.19 (1.02 to 1.38) | 0.024  |
| AGA (10th–90th centile)       | 4491   | 1 196 920 3.75                  | 1.00                    |         | 1.00           |         |
| LGA (>90th centile)           | 643    | 172 419 3.73                    | 0.95 (0.82 to 1.09)     | 0.426   | 0.97 (0.84 to 1.12) | 0.698  |
| APGAR 5 score                 |        |                                 |                         |         |                |         |
| <7 (abnormal)                 | 343    | 87 067 3.94                     | 1.05 (0.90 to 1.23)     | 0.541   | 0.92 (0.78 to 1.08) | 0.295  |
| ≥7 (healthy)                  | 5312   | 1 400 390 3.79                  | 1.00                    |         | 1.00           |         |
| Maternal                      |        |                                 |                         |         |                |         |
| Maternal age (years)          |        |                                 |                         |         |                |         |
| <20                           | 538    | 86 080 6.25                     | 1.53 (1.29 to 1.81)     | <0.001  | 1.51 (1.22 to 1.87) | <0.001 |
| 20–24                         | 1309   | 237 825 5.50                    | 1.39 (1.23 to 1.56)     | <0.001  | 1.37 (1.20 to 1.56) | <0.001 |
| 25–29                         | 1462   | 393 858 3.71                    | 1.00                    |         | 1.00           |         |
| 30–34                         | 1360   | 427 127 3.18                    | 0.90 (0.81 to 1.00)     | 0.060   | 0.92 (0.81 to 1.05) | 0.231  |
| 35+                           | 988    | 342 931 2.88                    | 0.82 (0.73 to 0.92)     | 0.001   | 0.80 (0.70 to 0.91) | 0.001  |
| Gravidity                     |        |                                 |                         |         |                |         |
| 0                             | 1620   | 479 189 3.38                    | 0.91 (0.79 to 1.04)     | 0.153   | 0.82 (0.70 to 0.95) | 0.010  |
| 1                             | 1437   | 396 836 3.62                    | 0.97 (0.84 to 1.11)     | 0.642   | 0.92 (0.78 to 1.07) | 0.278  |
| 2                             | 990    | 261 034 3.79                    | 1.00                    |         | 1.00           |         |
| ≥3                            | 1610   | 350 759 4.59                    | 1.16 (1.00 to 1.35)     | 0.047   | 1.14 (0.98 to 1.33) | 0.089  |
| Area                          |        |                                 |                         |         |                |         |
| Socioeconomic status          |        |                                 |                         |         |                |         |
| Most disadvantaged 1          | 809    | 103 279 7.83                    | 2.46 (1.93 to 3.14)     | <0.001  | 1.61 (1.30 to 2.00) | <0.001 |
| 2                             | 796    | 227 854 3.49                    | 1.17 (0.92 to 1.49)     | 0.199   | 1.04 (0.86 to 1.25) | 0.879  |
| 3                             | 838    | 190 211 4.41                    | 1.39 (1.06 to 1.80)     | 0.016   | 1.25 (1.03 to 1.51) | 0.023  |
| 4                             | 1464   | 404 092 3.62                    | 1.14 (0.89 to 1.47)     | 0.302   | 1.09 (~0.89 to 1.34) | 0.402  |
| Least disadvantaged 5          | 1603   | 525 038 3.05                    | 1.00                    |         | 1.00           |         |
| Geographic location           |        |                                 |                         |         |                |         |
| Major city                    | 1881   | 635 695 2.96                    | 1.00                    |         | 1.00           |         |
| Inner regional                | 1976   | 552 517 3.58                    | 1.26 (1.06 to 1.49)     | 0.008   | 1.11 (0.97 to 1.27) | 0.137  |
| Outer regional                | 624    | 115 243 5.41                    | 1.82 (1.48 to 2.24)     | <0.001  | 1.48 (1.26 to 1.75) | <0.001 |
| Remote                        | 202    | 40 877 4.94                     | 1.70 (1.27 to 2.26)     | <0.001  | 1.39 (1.06 to 1.84) | 0.018  |
| Very remote                   | 827    | 106 142 7.79                    | 2.72 (2.20 to 3.37)     | <0.001  | 1.82 (1.49 to 2.22) | <0.001 |

*Adjusted for Indigenous status, socioeconomic status, maternal age, gravidity, gender of child, birth weight.
†Prematurity was not adjusted for birth weight due to collinearity.
AGA, appropriate for gestational age; IRR, incident rate ratio; aIRR, adjusted incident rate ratio; LGA, large for gestational age; SGA, small for gestational age.
There was an increased incidence of emergency department presentation for the most remote preterm infants (7.8/1000 person days) compared with non-remote preterm infants (3.0/1000 person days; aIRR 1.82, 95% CI 1.49 to 2.22; table 2). There was also some evidence of a dose–response for increased incidence of emergency department presentation with increased levels of remoteness overall (p value for trend<0.001; table 2) and for Indigenous (p value for trend<0.001) and non-Indigenous (p value for trend<0.001) preterm infants (table 3). Remote area preterm infants had a higher but not significant incidence of hospitalisation (4.1/1000 person days) compared with the least remote preterm infants (3.3/1000 person days; aIRR 1.09, 95% CI 0.92 to 1.29; table 2). There was also some evidence of a dose–response with increased risk of hospital admission with increased levels of remoteness for Indigenous preterm infants (p value for trend=0.043); however, there was no trend for non-Indigenous preterm infants (p value for trend=0.252) and overall (p value for trend=0.058) preterm infants (tables 2 and 3).

Overall, the distribution of causes was similar in Indigenous and non-Indigenous infants (table 4). Indigenous infants appeared more likely to be hospitalised for respiratory disease (1.6/1000 person days) than non-Indigenous infants (0.5/1000 person days; table 4). Indigenous infants appeared more likely to be hospitalised for infectious and parasitic diseases (0.4/1000

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### Table 3

|                  | Indigenous |                  | Non-Indigenous |                  |
|------------------|------------|------------------|----------------|------------------|
|                  | Events     | Time at risk     | (Events/risk)×1000 | aIRR×(95% CI)*  |
|                  |            |                  |                |                  |
| **Hospital admissions** |            |                  |                |                  |
| Socioeconomic status |            |                  |                |                  |
| Most disadvantaged 1 | 300        | 56 795           | 5.28            | 1.29 (0.93 to 1.80) |
| 2                | 98         | 20 178           | 4.86            | 1.08 (0.74 to 1.58) |
| 3                | 88         | 19 685           | 4.47            | 0.92 (0.61 to 1.38) |
| 4                | 130        | 26 672           | 4.87            | 1.12 (0.68 to 1.84) |
| Least disadvantaged 5 | 97         | 22 800           | 4.25            | 1.00              |
| p Value trend    | 0.654      |                  |                |                  |
| **Geographic location** |            |                  |                |                  |
| Most remote      | 331        | 66 865           | 4.95            | 1.51 (1.10 to 2.06) |
| Outer regional   | 117        | 20 521           | 5.70            | 1.56 (1.02 to 2.39) |
| Inner regional   | 159        | 28 882           | 5.51            | 1.58 (1.14 to 2.21) |
| Major city       | 106        | 29 861           | 3.55            | 1.00              |
| p Value trend    | 0.437      |                  |                |                  |
| **Emergency presentations** |            |                  |                |                  |
| Socioeconomic status |            |                  |                |                  |
| Most disadvantaged 1 | 544        | 56 795           | 9.58            | 1.03 (0.74 to 1.41) |
| 2                | 108        | 20 178           | 5.35            | 0.57 (0.40 to 0.81) |
| 3                | 159        | 19 685           | 8.08            | 0.87 (0.62 to 1.22) |
| 4                | 167        | 26 672           | 6.26            | 0.63 (0.43 to 0.94) |
| Least disadvantaged 5 | 207       | 22 800           | 9.08            | 1.00              |
| p Value trend    | 0.004      |                  |                |                  |
| **Geographic location** |            |                  |                |                  |
| Most remote      | 641        | 66 865           | 9.59            | 1.92 (1.53 to 2.40) |
| Outer regional   | 178        | 20 521           | 8.67            | 1.65 (1.31 to 2.09) |
| Inner regional   | 206        | 28 882           | 7.13            | 1.38 (1.02 to 1.86) |
| Major city       | 160        | 29 861           | 5.36            | 1.00              |
| p Value trend    | 0.001      |                  |                |                  |

*Adjusted for maternal age, gravidity, sex of child, birth weight.

aIRR, adjusted incidence rate ratio.
than non-Indigenous infants (0.2/1000 person days; table 4). However, the numbers were too small to perform statistical tests.

In our WA population-based study, 53% of preterm infants presented to a hospital emergency department and 74% were admitted in the time between discharge from birth admission to 11 months of chronological age. Incidence of hospital admission and emergency department presentation was 1.2-fold to 1.7-fold greater in Indigenous compared with non-Indigenous infants. Preterm infants located in the poorest and most remote areas of WA had significantly greater hospital usage compared with preterm infants living in less poor and urban areas. In the past 10 years, there have been a number of studies showing that preterm infants are at greater risk of hospital admission and emergency presentation compared with term infants. However, few have investigated whether preterm infants from vulnerable families have an increased risk of hospital usage compared with the general population. Hispanic and African-American preterm infants have been reported to have a greater risk of hospital admission and emergency presentation compared with white preterm infants. Bar-Zeev et al reported that 60% of Indigenous preterm infants were readmitted to hospital in the first year of life compared with only 44% of Indigenous term infants. However, there have been no published reports of the differences in hospital usage between Australian Indigenous and non-Indigenous preterm infants in the past 10 years. Population-based studies in infants of all gestational ages have shown increased risk of hospital admission, length of stay and emergency presentation in socially disadvantaged infants compared with the least disadvantaged infants. We reported that the most disadvantaged preterm infants had a 60% greater incidence of emergency department presentations compared with infants from the most advantaged areas. Although preterm infants are more likely to be born to families who are socially disadvantaged, we located no other studies that examined how socioeconomic status may influence subsequent hospital use in preterm infants. Preterm infants living in remote areas in our study had a 1.1-fold to 1.8-fold greater risk of presenting to the emergency department and hospital admission compared with the least remote infants. Population-based studies have reported that infants located in remote areas have an increased risk of readmission and emergency department presentation in the first 6 weeks after birth. However, we were unable to locate other studies that examined the effect of geographic location on hospital admission. We also showed that length of stay for the birth admission was significantly associated with subsequent hospital admissions and emergency department presentations. We found that infants who were admitted longer than the median length of stay were 1.8-fold greater risk of presenting to the emergency department and were more likely to be readmitted. Population-based studies have shown increased risk of hospital admission and emergency presentation in socially disadvantaged areas. Other studies have shown increased risk of hospital admission and emergency presentation in socially disadvantaged areas. We reported that 60% of Indigenous preterm infants were readmitted to hospital in the first year of life compared with only 44% of Indigenous term infants. Despite this, few have investigated whether preterm infants living in less poor and urban areas had significantly greater hospital usage compared with preterm infants living in the poorest and most remote areas of WA. In the past 10 years, there have been a number of studies showing that preterm infants are at greater risk of hospital admission and emergency presentation compared with term infants. Despite this, few have investigated whether preterm infants living in less poor and urban areas had significantly greater hospital usage compared with preterm infants living in the poorest and most remote areas of WA.

### Table 4

ICD-10 classification of primary cause of hospital admissions in preterm infants postdischarge from birth admission to 11 months by Indigenous status, 2010–2011

| Primary cause of hospital admission | Total | Indigenous | Non-Indigenous |
|-----------------------------------|-------|------------|----------------|
| | Events | Time at risk | (Events/risk)×1000 (95% CI) | Events | Time at risk | (Events/risk)×1000 (95% CI) | Events | Time at risk | (Events/risk)×1000 (95% CI) |
| Respiratory system | 620 | 1 091 028 | 0.57 (0.53 to 0.65) | 178 | 1 134 466 | 1.57 (1.27 to 2.00) | 442 | 977 562 | 0.45 (0.42 to 0.52) |
| Infectious and parasitic diseases | 188 | 1 091 028 | 0.17 (0.14 to 0.20) | 45 | 1 134 466 | 0.40 (0.26 to 0.56) | 143 | 977 562 | 0.15 (0.12 to 0.17) |
| Digestive system | 212 | 1 091 028 | 0.19 (0.17 to 0.24) | 23 | 1 134 466 | 0.20 (0.13 to 0.33) | 189 | 977 562 | 0.19 (0.17 to 0.24) |
| Skin and subcutaneous tissue | 36 | 1 091 028 | 0.03 (0.02 to 0.05) | NP | NP | NP | NP | NP | NP |
| Ear and mastoid process | 39 | 1 091 028 | 0.04 (0.03 to 0.05) | 12 | 1 134 466 | 0.11 (0.05 to 0.18) | 27 | 977 562 | 0.03 (0.02 to 0.04) |
| Nutritional diseases | 15 | 1 091 028 | 0.01 (0.01 to 0.02) | NP | NP | NP | NP | NP | NP |
| Injury and poisoning | 57 | 1 091 028 | 0.05 (0.04 to 0.07) | 12 | 1 134 466 | 0.11 (0.04 to 0.16) | 45 | 977 562 | 0.05 (0.03 to 0.06) |
| Perinatal conditions | 3354 | 1 091 028 | 3.07 (3.02 to 3.14) | 358 | 1 134 466 | 3.16 (2.95 to 3.40) | 2996 | 977 562 | 3.06 (3.01 to 3.14) |
| Congenital malformations, deformations and chromosomal abnormalities | 169 | 1 091 028 | 0.15 (0.13 to 0.18) | 113 | 1 134 466 | 0.10 (0.03 to 0.16) | 158 | 977 562 | 0.16 (0.13 to 0.19) |
| Other | 594 | 1 091 028 | 0.54 (0.49 to 0.62) | 101 | 1 134 466 | 0.89 (0.53 to 1.26) | 493 | 977 562 | 0.50 (0.46 to 0.58) |
| Total admissions | 5284 | 1 091 028 | 4.84 (4.78 to 5.04) | 745 | 1 134 466 | 6.57 (6.05 to 7.36) | 4539 | 977 562 | 4.64 (4.58 to 4.82) |

NP, not publishable due to small numbers and confidentiality restrictions.

ICD-10, International Classification of Disease V.10.
presentations. Length of hospital stay can be seen as a proxy for the health status and ‘unwellness’ of the child during the hospital admission. It has been shown in many studies to have a clear influence on subsequent hospital usage.25 26

Over the past 10 years, there has been significant Australian Federal Government funding to improve access to urban, rural and remote paediatric services including building hospitals, clinics and Aboriginal Community Controlled Health Services (ACCHS).27 28 There has also been an increase in staffing levels of all healthcare providers in rural and remote areas and major investments in specialist outreach services and care coordination. In WA, there is free antenatal care and culturally appropriate midwifery and postdischarge care for disadvantaged mothers and infants, home visits within 72 hours of discharge,29 regular medical and developmental follow-up of all preterm infants,30 and universal and targeted surveillance and screening programmes.29 31 It is highly likely that these initiatives have improved health status and subsequent morbidity and mortality risks. However, our study shows that important inequities remain in service use in remote areas, in poor families and in Indigenous families.

The most common causes of hospitalisation were respiratory, and infectious and parasitic diseases in Indigenous and non-Indigenous preterm infants. Respiratory disease has previously been cited as the most common cause for hospital admissions for Indigenous infants up to 12 months in the Northern Territory32 and WA.24 For all preterm infants under 12 months of age, respiratory and infectious conditions have repeatedly been shown to be the main cause of admission.26 32 Many of these conditions are preventable by improving coverage of routine childhood vaccines such as pneumococcal and rotavirus vaccines and also through improving housing and education levels in families. Cause of emergency presentations was not assessed in this study due to no data being available; however, existing evidence suggests that many emergency presentations may also be the result of potentially avoidable conditions.17 33 Our data indicate that more can be done to improve health services and reduce hospital use in preterm infants in WA. We are also aware that the underlying socioeconomic determinants of health such as education and employment are also important determinants of health service use and many improvements are needed in these areas.

Our study had some limitations. Our study was observational and could only report associations and did not provide proof of causality. Indigenous status can be missing or misclassified, which may result in an underestimation of risk.34 35 Despite this, our results show a highly significant effect of Indigenous status on hospital usage and it is unlikely that any misclassification would have biased the results. Where available, we adjusted for all potential confounding factors. However, we were unable to adjust for measures of maternal illness or education or any underlying social conditions (eg, housing and infrastructure) that may have played a role in hospital usage, particularly preventable causes of hospital use.36 Within Australia, socioeconomic data are primarily based on AIHW IRSD quintiles which can cause misclassification when applied at an individual level.11 However, we did show strong associations between hospital usage and socioeconomic status and any differential misclassification would have biased towards the null. Small sample size for Indigenous preterm infants in some of the subanalyses could have resulted in a type II error as a result of reduced power to detect true differences. We did not have the mode of separation variable in our data; therefore, we are unable to determine whether a baby was discharged home or transferred to another hospital following the length of stay at the birth hospital. However, our length of stay data are similar to previously reported data from New South Wales (Australia) which were published earlier in 2016 (median length of stay for infants <28 weeks gestation 87 (IQR 31) and median length of stay for infants 28–23 weeks gestation 47 (IQR 23)).26

There are strengths related to the data collections we used. The cause-specific hospitalisation data were limited to primary cause of hospitalisation. These data are considered to be highly accurate,10 37 because the Hospital Morbidity Data System uses the WHO ICD-10 coding system15 and highly trained coders. The Midwives’ Notification System uses clear definitions that are based on Australian standard definitions5 and is reported to have a very high level of completion and clinical certainty.38 39 Our emergency department presentations were also recorded in a clearly defined patient administration system Emergency Department Information System (EDIS).40 41 This system is considered by emergency department staff to be highly reliable though formal documentation of its accuracy is not available. In contrast, the accuracy of cause-specific emergency department data has been questioned,33 which is why we did not include cause-specific emergency department data in this study. Finally, we controlled for confounding effects of multiple births by restricting the analysis to singleton births.

Our study has implications for policy and programme development. Despite investments in maternal and child health services, we reported that preterm infants had high hospital usage rates and that important risk groups were infants living in disadvantaged areas, remote area infants and Indigenous infants. Our data highlight the need for improved postdischarge care of preterm infants, particularly in remote regions and for poor, Indigenous infants. This includes preventive programmes focused on improving skills of families and service providers in caring for small infants and care coordination programmes. The WA government has provided recent funding to improve postdischarge care and care coordination for Indigenous children across WA. These interventions have the potential to improve education on the causes of hospitalisations.
hospital usage and long-term health outcomes of these vulnerable infants and reduce long-term burden on families. We will continue to monitor impacts and report

trends in subsequent papers.

Author affiliations
1School of Paediatrics and Child Health, The University of Western Australia, Perth, Western Australia, Australia
2Princess Margaret Hospital for Children, Perth, Western Australia, Australia
3Kurongkurl Katjinyj, Centre for Indigenous Australian Education and Research, Edith Cowan University, Perth, Western Australia, Australia
4School of Psychology and Exercise Science, Murdoch University, Perth, Western Australia, Australia

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Contributors
SP, KME, DRM and RM conceived and designed the experiments. NAS and KEM performed the experiments. NAS, KEM and KME analysed the data. NAS contributed reagents/materials/analysis tools. NAS, SP, KEM, DRM, RM and KME wrote the paper.

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Competing interests
None declared.

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WA Department of Health Human Research Ethics Committee, the University of Western Australia Human Research Ethics Committee, and the Western Australian Aboriginal Health Ethics Committee (WAAHEC).

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Data are available from the Western Australia Department of Health Data Linkage Branch with ethical approval through the Western Australia Department of Health Human Research Ethics Committee (Ref 2013/33). To maintain confidentiality and security, interested individuals may apply for access to linked data by contacting the Western Australian Data Linkage Branch. Contact details are DataServices@health.wa.gov.au; +61-8-9222 2370. The computing code is available on request from the corresponding author.

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