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Severe Neonatal Morbidity Among Births to Refugee Women

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Abstract *Background* Despite being considered high risk, little is known about the perinatal health of refugees in developed countries. Our objectives were to examine whether: (1) the healthy migrant effect applies to infants born to refugee women with respect to severe neonatal morbidity (SNM); (2) refugee status was a risk factor for SNM among immigrants; (3) refugee sponsorship status was a risk factor for SNM by comparing asylum-seekers to sponsored refugees; and (4) refugees were at greater risk of specific SNM subtypes. *Methods* Immigration records (1985–2010) linked to Ontario hospital data (2002–2010) were used to examine SNM. We calculated adjusted risk ratios (ARR) with 95 % confidence intervals (95 % CI) for SNM and unadjusted risk ratios with 99 % CI for SNM subtypes using log-binomial regression. *Results* There were borderline differences in SNM among refugees (N = 29,755) compared to both non-immigrants (N = 860,314) (ARR = 0.94, 95 % CI 0.89, 0.99) and other immigrants (N = 230,847) (ARR = 1.10, 95 % CI 1.04, 1.18) with a larger difference comparing other immigrants to non-immigrants (ARR = 0.83, 95 % CI 0.81, 0.85). Asylum-seekers did not differ from sponsored refugees (ARR = 1.07, 95 % CI 0.90, 1.27). Though rare, several SNM subtypes were significant with large effect sizes. *Conclusion* With respect to SNM risk, the healthy migrant effect clearly applies to non-refugee immigrants, but is weaker for refugees and may not apply. Among immigrants, refugee status was a weak risk factor for SNM and may not be clinically important. Sponsorship status was not associated with greater risk of SNM. Further investigation of several SNM subtypes is warranted.

Keywords Refugees · Severe neonatal morbidity · Healthy migrant effect · Administrative data

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Significance

What is already known on this subject? Little is known about severe neonatal morbidity (SNM) among infants born to refugee women in developed countries. Exposures associated with migration (i.e., malnutrition, access to settlement supports) may increase the risk of SNM among refugees, suggesting that: (1) the healthy migrant effect may not apply; (2) refugee status may be a risk factor; and

(3) lack of settlement support may be associated with greater risk.

What this study adds? With respect to SNM, the healthy migrant effect applies to other immigrants but not to refugees, refugee status may not be a clinically important risk factor, and lack of settlement support does not affect SNM.

Introduction

In 2014, the United Nations recorded 19.5 million refugees around the globe [20]. Refugees involuntarily flee their country of origin because of persecution, conflict or generalized violence and are unable or afraid to return home. Refugee immigration to Canada has been described in detail elsewhere [28]. About 10 % of the 250,000 new immigrants admitted annually arrive as refugees while the majority enter for economic reasons (55 %) or family reunification (35 %). Refugees differ from other immigrants to Canada in that their admission does not depend on the "points system"—levels of education, language fluency and work experience on which economic immigrants are scored for immigration. In this way, pre-migration social determinants of health are different for refugees than for other immigrants. Refugee status may also be correlated with long-standing social disadvantage (resulting from persecution) irrespective of characteristics associated with the "points system". Factors such as malnutrition, present in many protracted refugee situations around the world [5], sexual violence [27] and psychosocial stress [30] are important risk factors for refugee women and may set them apart from their non-refugee immigrant counterparts. All factors are linked to adverse perinatal outcomes [1, 8, 31].

Given immigrant selection and such pre-migration risk factors it has been postulated that refugees, unlike other immigrants, may not exhibit the healthy migrant effect [7]—the phenomenon whereby foreign-born individuals are healthier than native-born residents [24]. Given this background we will test two hypotheses. Firstly, that the healthy migrant effect does not apply to infants born to refugees but will apply to other immigrants. Secondly, that refugee status is an independent risk factor for adverse perinatal outcomes among immigrants.

Post-migration risk factors may also adversely affect the health of refugees and their infants. In Canada, sponsorship status dictates the levels of settlement assistance provided. Refugees arrive to Canada under two broad sub-classes: (1) sponsored and (2) non-sponsored. Sponsored refugees are referred for re-settlement by the UNHCR and are sponsored by the Government of Canada or a private organization [2]. Upon arrival, they become "permanent residents" and are eligible for provincially funded health care [3] and resettlement assistance [9]. Non-sponsored refugees comprise refugee claimants (or "asylum seekers") who arrive in Canada using personal resources, increasingly under precarious circumstances, and claim asylum. They are eligible for short-term federal health care coverage while their application is being processed, however it has been noted that not all clinicians accept the coverage which may pose a barrier to care [12]. Refugee claimants *may* also be eligible for provincial social assistance, although this is not assured [4]. With approval of their claim, refugee claimants are transferred to the provincial health care plan (Citizenship and Immigration Canada, 2012). Considering different migration pathways, health care funders and lower access to social services (particularly in the early years of settlement), infants born to non-sponsored refugees may have poorer health. Differences between non-sponsored and sponsored refugees will be examined in this study.

There have been a number of studies that have examined the perinatal health of infants of refugee women [6, 10, 11, 13, 15, 16, 18, 19, 26, 29]. These studies covered many perinatal outcomes but many studies were underpowered given the frequency of the outcome or did not adequately adjust for important confounders such as maternal age or parity. Those studies of higher quality [10, 26, 29] either suggest refugees *do not* experience the healthy migrant effect (the two former) or that refugee status is a risk factor (the latter). The two former studies indicate markedly higher risk of perinatal mortality, fetal distress, Agpar score below 7 and prelabor fetal death for foreign-born women (mostly African, thought to be refugees) compared to native-born women and the latter study found higher risk of preterm birth among refugees compared to other immigrants. No studies have examined the potential impact of refugee sponsorship.

No gold standard exists for the measurement of severe neonatal morbidity and the measures used, such as admission to a neonatal intensive care unit (NICU) or individual morbidities captured in hospitalizations data, have limitations [17]. To overcome these measurement problems, a neonatal morbidity indicator that enumerates multiple severe neonatal outcomes simultaneously and based on hospitalizations data is considered both practical and efficient while still meaningful. In 2012, Lain et al. [17] published findings using such a composite indicator, referred to as the *Neonatal Adverse Outcomes Indicator (NAOI)*. The diagnostic and procedure codes included in the indicator relate to different body systems (i.e., respiratory system). The researchers found that infants identified by the NAOI were ten times more likely to die and twice as likely to be readmitted to hospital in the first year of life compared to infants not identified by the NAOI. The authors concluded that NAOI is a cost effective way to

monitor temporal trends, assess interventions and the quality of perinatal care. To our knowledge, we are the first to adapt this indicator for use with Canadian hospitalization data. In our work, we refer to it as an indicator of severe neonatal morbidity (SNM).

This study had four objectives. The first objective was to assess the extent that a healthy migrant effect with respect to SNM risk was operative among refugees and other immigrants compared to non-immigrants. Secondly, we identify whether refugee status was an independent risk factor for SNM among immigrants. Thirdly, we examine whether sponsorship status was associated with SNM risk among refugees. Lastly, we examine whether refugees were at greater risk of specific SNM subtypes compared to other immigrants and to non-immigrants. Addressing these gaps will provide robust baseline information on a potentially vulnerable group of women and infants and, if necessary, guide intervention, research and allocation of additional health care resources aimed at improving outcomes.

Methods

Study Design and Inclusion/Exclusion Criteria

This population-based database study included all Ontario hospital-based singleton live births that occurred between April 1, 2002 and March 31, 2011. Births to refugee women and other immigrant women were identified retrospectively through linkage of hospital deliveries to the Immigration and Refugees Citizenship Canada Permanent Resident Database (IRCC PRD) (1985–2010). Consistent with the United Nations definition, the IRCC defines a *refugee* as someone with a well-founded fear of persecution based on race, religion, nationality, membership in a particular social group or political opinion (United Nations High Commissioner for Refugees, 2015). *Other Immigrants (or non-refugees)* had non-refugee migration histories. Those births not linked to the CIC database were attributed to *non-immigrant* women, the majority of whom were born in Canada. All women included in this study were eligible for provincial health care insurance.

Implicit in this study is that exposures prior to reaching reproductive age (<15 years old) affect maternal and perinatal outcomes later in life. To ensure different settings for reproductive development—foreign settings for immigrants and Canada for non-immigrants, are being compared, only women who were ≥15 years old at the time of arrival to Canada were included. As a result, all refugee, immigrant and non-immigrant women who were <15 years old at the time of the index birth were excluded. We also excluded women ≥50 years of age at the time of index birth to limit to the reproductive age range. The unit of analysis was the singleton live birth, excluding births with gestational ages <22 weeks or birth weights <500 g, because these are considered below the limits of viability (i.e., low survival) and may not routinely be registered.

Data Sources

We deterministically linked (via an encrypted health card number) two administrative databases held at the Institute for Clinical and Evaluative Sciences (ICES) in Toronto, Ontario. First, records for any singleton live birth occurring in an Ontario hospital were obtained from the Discharge Abstract Database (DAD) which originates from the Canadian Institute of Health Information (CIHI). Diagnosis and procedure codes (defined by, the 10th revision of the *International Statistical Classification of Diseases and Related Health Problems*, Canadian enhancement, and *Canadian Classification of Health Interventions*—ICD-10-CA/CCI) were used to identify infants with any severe neonatal morbidity. A study examining the validity of perinatal data available in the DAD suggested that both diagnoses and procedures are accurately coded and supported use of this database for perinatal research [14]. This dataset also contained information on maternal age at the time of birth and parity.

Second, immigrants' arrival records for those who received permanent residency were obtained from the Immigration and Refugee Citizenship Canada Permanent Resident Database (IRCC PRD), the official Canadian immigration registry. The IRCC PRD contains information on refugee status (refugee and other immigrant), refugee sponsorship status, the date of becoming a permanent resident, country of birth, as well as education level and knowledge of Canadian official languages upon arrival to Canada. To determine health card numbers (encrypted), the IRCC PRD was linked (86.36 % success rate—68.15 % deterministic, 18.22 % probabilistic) to a database of all Ontarians eligible for publicly funded universal health care insurance. An initial study of this linkage suggested little bias between linked and unlinked records. The IRCC PRD linked database has been used in numerous maternal and perinatal epidemiological studies [22, 23, 28, 29].

Outcome of Interest

Severe neonatal morbidity (SNM), the outcome of interest, is based on a composite indicator referred to as the *neonatal adverse outcomes indicator* (NAOI) developed in Australia [17]. The Australian diagnosis and procedure codes were mapped over to the ICD-10-CA/CCI system by the lead

author (SW), in collaboration with an expert clinician and a general surgeon (see Table S1 for a list of codes). The major modifications to the NAOI for use in Canada were to exclude: neonatal mortality as a subtype, adult codes for sepsis and pneumonia (codes not beginning with 'P'), and multiple births. We found adequate concurrent and predictive validity. Our dichotomous SNM indicator was operationalized as any singleton live birth with one or more of the ICD-10-CA/CCI diagnosis or procedure codes for SNM recorded during the birth admission.

Exposure and Covariates

The exposure group of interest was infants of refugees who were compared to infants of non-immigrants and other immigrants (objectives 1, 2 and 4). For the third objective, non-sponsored refugees' (refugee claimants) infants were compared to sponsored refugees' (government-assisted and privately sponsored refugees) infants. The refugee sub-group "Refugee dependents" are included in objectives 1, 2 and 4 but are excluded from objective 3 since their application is tied to a refugee classified in one of the other three groups.

Covariates included: Maternal age recorded at the time of delivery (categories: 15–19, 20–24, 25–29, 30–34, 35–39, 40+ years) and Parity (categories: 1, 2 and $\geq$3 previous births).

Some covariates were only available for refugees and immigrants since this information was collected by the IRCC. Maternal birth place included country of birth and world regions. Regions were categorized according to the United Nations Geographical classification system [21] with a modification to the suggested "Developed" country category which excluded Eastern and Southern Europe, since millions of refugees fled countries in these regions stemming from the Bosnian War. Education at the time of arrival was described as 0–9, 10–12, 13+ years (exclusive of other categories), trade certificate and non-university diploma and bachelor/masters/doctorate. Knowledge of official languages at arrival was categorized as knowledge of one or both official Canadian languages (English, French) or knowledge of neither. Duration of residence in Canada was defined as the time (in years) elapsed between the date of becoming a permanent resident and the date of infant birth.

Analytic Methods

Cumulative incidence of any SNM was reported as a proportion of all singleton live births. For all models, log-binomial regression was used to estimate unadjusted risk ratios (RR) and adjusted risk ratios (ARR) with 95 % confidence intervals (95 % CI). Since risk can be estimated directly with this population-based study design, log-binomial regression was preferred over logistic regression which is more amenable to a case–control design that must model the odds. Refugees and other immigrants were compared to non-immigrants (Model 1), refugees to other immigrants (Model 2) and non-sponsored refugees to sponsored refugees (Model 3).

In Model 1, maternal age and parity were considered confounders a priori (associated with the exposure, causally related to the outcome and not a mediating variable between the exposure and the outcome). Fewer confounders were available for adjustment in Model 1 since many socio-demographic factors were only captured for refugees and immigrants.

In Models 2 and 3, unadjusted models included a random intercept for maternal country of birth, considered a contextual variable in these analyses, which allowed us to account for the potential similarity of SNM among infants born to women from the same country of birth. From an intercept only model (no explanatory variables), the significance of the random intercept co-efficient for each model was noted and if significant, the intra-class correlation co-efficient (ICC) was calculated to quantify the correlation in SNM risk between infants born to mothers from the same country of birth. For ARRs in Models 2 and 3, in addition to including a random intercept for country of birth, confounders were identified a priori and included maternal age, parity, education level, language ability and duration of residence (as fixed effects).

To compare SNM subtypes among refugees to i) non-immigrants and ii) other immigrants, the cumulative incidence of SNM subtypes was modeled to estimate unadjusted risk ratios (RR) and 99 % confidence intervals (99 % CI). Given the numerous SNM subtypes, more conservative 99 % CIs rather than the usual 95 % CIs were estimated to account for multiple hypothesis testing and to compensate for increased chances of a Type 1 error.

This study was approved by the research ethics boards of the University of Toronto, St. Michael's Hospital and Sunnybrook Health Sciences Centre.

Results

The incidence of SNM and corresponding population size of the study groups were 4.6 % (N = 29,765), 4.2 % (N = 230,914) and 5.0 % (N = 860,617) for births to refugees, immigrants and non-immigrants, respectively (Table 1). A greater proportion of refugees had less than 12 years of education at arrival (66.1 %) compared with other immigrants (37.9 %). Approximately equal proportions of refugees were born in South Asia (29.4 %) and Sub Saharan Africa (29.4 %) with a much larger proportion born in the latter compared to other immigrants (5.3 %). Approximately 80 % of both refugee and other immigrants delivered within the first 10 years of arrival to Canada.

Table 1 Characteristics of singleton births (2002–2010) to refugees, other immigrants, non-immigrant, non-sponsored refugee and sponsored refugee women

	Refugees (N = 29,765)		Other immigrants (N = 230,914)		Non-immigrants (N = 860,617)		Non-sponsored refugees (N = 15,122)		Sponsored refugees (N = 10,571)	
Infant measurements	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Birthweight (g)	3372.0	551.5	3293.7	529.4	3431.6	559.7	3358.4	554.6	3412.6	552.1
Gestational age (weeks)	38.9	1.8	38.9	1.8	38.9	1.8	38.9	1.9	39.0	1.8
Characteristics	N	%	N	%	N	%	N	%	N	%
Count of severe neonatal morbidity (SNM) subtypes										
None	28,385	(95.4)	221,276	(95.8)	817,397	(95.0)	14,410	(95.3)	10,787	(95.4)
≥1	1380	(4.6)	9638	(4.2)	43,220	(5.0)	712	(4.7)	484	(4.6)
Maternal age at birth (years)										
15–19	278	(0.9)	1060	(0.5)	39,839	(4.6)	143	(1.0)	90	(0.9)
20–24	2855	(9.6)	22,272	(9.7)	124,115	(14.4)	1316	(8.7)	923	(8.7)
25–29	7678	(25.8)	67,728	(29.3)	238,682	(27.7)	4100	(27.1)	2332	(22.1)
30–34	10,233	(34.4)	82,151	(35.6)	289,766	(33.7)	5548	(36.7)	3473	(32.9)
35–39	6815	(22.9)	47,007	(20.4)	141,187	(16.4)	3205	(21.2)	2865	(27.1)
40+	1906	(6.4)	10,696	(4.6)	27,028	(3.1)	800	(5.3)	888	(8.4)
Missing	0	(0.0)	0	(0.0)	0	(0.0)	0	(0)	0	(0)
Parity (previous births)										
None	9336	(31.4)	98,000	(42.5)	395,614	(46.0)	4912	(32.5)	3122	(29.5)
1	9725	(32.7)	88,302	(38.3)	303,891	(35.3)	4981	(33.0)	3298	(31.2)
2	5589	(18.8)	31,009	(13.4)	111,130	(12.9)	2772	(18.3)	2016	(19.1)
3 or more	5105	(17.2)	13,536	(5.9)	49,679	(5.8)	2441	(16.2)	2132	(20.2)
Missing	10	(0.0)	67	(0.0)	303	(0.0)	6	(0.0)	3	(0.0)
Language ability										
English	17,402	(58.5)	136,520	(59.1)	Not available		13,455	(89.0)	2947	(27.9)
French	759	(2.6)	2414	(1.1)			486	(3.2)	159	(1.5)
Both English and French	608	(2.0)	6775	(2.9)			382	(2.5)	193	(1.8)
Neither	10,996	(37.0)	85,200	(36.9)			789	(5.2)	7272	(68.8)
Missing	0	(0.0)	5	(0.0)			0	(0)	0	(0)
Education level										
0–9 years	8750	(29.4)	31,493	(13.6)	Not available		3186	(21.1)	4153	(39.3)
10–12 years	11,217	(37.7)	56,192	(24.3)			5970	(39.5)	3811	(36.1)
13+ years[a]	3282	(11.0)	25,310	(11.0)			2006	(13.3)	841	(8.0)
Trade certificate, non-university diploma	3796	(12.8)	32,127	(13.9)			2182	(14.4)	1184	(11.2)
Bachelors, Masters, Doctorate	2720	(9.1)	85,792	(37.1)			1768	(11.7)	582	(5.5)
Missing	0	(0.0)	0	(0.0)			0	(0)	0	(0)
Region of maternal birth										
Sub Saharan Africa	8716	(29.3)	12,174	(5.3)			5305	(35.1)	2776	(26.3)
South Asia	8749	(29.4)	83,303	(36.1)			4322	(28.6)	2596	(24.6)
Latin America and Caribbean	3035	(10.2)	25,717	(11.2)			2066	(13.7)	678	(6.4)
Western and Central Asia	2673	(9.0)	14,241	(6.2)	Not applicable		1073	(7.1)	1231	(11.6)
East Asia	1649	(5.5)	32,005	(13.9)			959	(6.4)	36	(0.3)
Eastern Europe	1931	(6.5)	15,985	(6.9)			783	(5.2)	975	(9.2)
Southern Europe	1875	(6.3)	5933	(2.6)			355	(2.4)	1471	(13.9)
Southeast Asia, Oceania Islands	838	(2.8)	25,541	(11.1)			55	(0.4)	762	(7.2)
North Africa	161	(0.0)	3572	(1.6)			121	(0.1)	19	(0.1)
Developed[b]	120	(0.5)	12,289	(4.7)			73	(0.0)	22	(0.0)
Missing	5	(0.0)	82	(0.0)			0	(0.0)	5	(0.0)

Table 1 continued

Characteristics	N	%	N	%	N	%	N	%	N	%
Duration of residence at birth (years)										
≤4[c]	14,239	(47.8)	127,906	(55.4)	Not applicable		8570	(56.7)	3215	(30.4)
5–9	8188	(27.5)	65,341	(28.3)			4189	(27.7)	2800	(26.5)
10–14	5339	(17.9)	28,144	(12.2)			2013	(13.3)	2940	(27.8)
15–19	1850	(6.2)	8635	(3.7)			340	(2.3)	1469	(13.9)
20+	147	(0.5)	883	(0.4)			0	(0.0)	145	(1.4)
Missing	2	(0.0)	5	(0.0)			0	(0)	2	(0)

[a] 13+ age category is exclusive of other categories, did not complete a subsequent qualification

[b] Developed Countries: modified suggested UN classification excluding Eastern and Southern Europe (includes United States, Bermuda,Western and Northern Europe, Japan, Australia and New Zealand)

[c] ≤4 category includes a small proportion of women who delivered prior to receiving permanent residence and prior to eligibility for the Ontario Health Insurance Plan (OHIP)

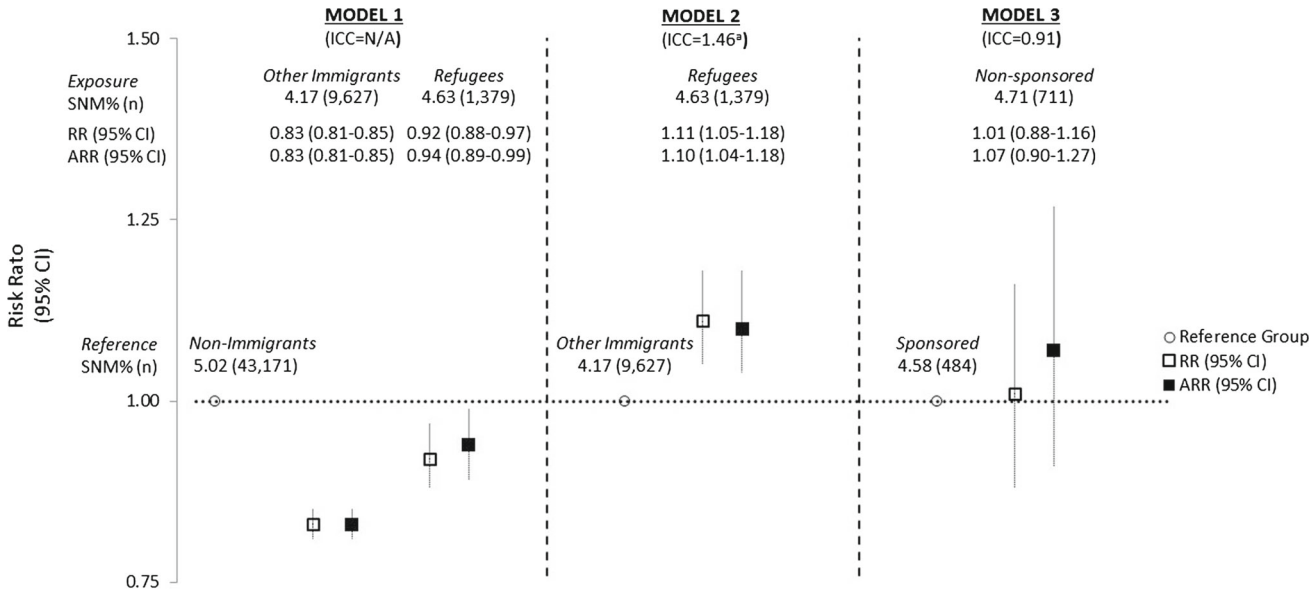
The incidence of SNM among non-sponsored refugees (N = 15,122) was 4.7 % compared to 4.6 % among sponsored refugees (N = 10,571). A greater proportion of non-sponsored refugees compared to sponsored refugees knew either English or French (92.2 vs. 29.4 %) and had higher levels of education (13 +, post-secondary—39.4 vs. 24.7 %). Almost double the proportion of births to non-sponsored refugees compared to sponsored refugees occurred within the first 4 years of receiving permanent residency (56.7 vs. 30.4 %) with 20 % (vs. 0.1 %) of these occurring prior to receiving permanent residency.

Multivariable models (Fig. 1) revealed that infants born to both refugees and immigrants had significantly *lower risk* of any SNM when compared to infants born to non-immigrants (ARR = 0.94; 95 % CI 0.89, 0.99 and ARR = 0.83; 95 % CI 0.81, 0.85, respectively) (Model 1). Conversely, refugees experienced a marginally significantly *higher risk* in comparison to immigrants (ARR = 1.10; 95 % CI 1.04, 1.18) (Model 2). The ICC for Model 2 was statistically significant and indicated that there was only a 1.5 % correlation in risk of SNM among infants born to mothers from the same country of birth. Risk of SNM did not differ between infants born to non-sponsored refugees and infants born to sponsored refugees (ARR = 1.07; 95 % CI 0.90, 1.27) (Model 3).

Eight SNM subtypes were significantly higher among refugees compared to other immigrants: any intravenous fluids (RR = 1.22; 99 % CI 1.08, 1.39), central venous/arterial catheter (RR = 1.33; 99 % CI 1.02, 1.73), seizure (RR = 1.59; 99 % CI 1.15, 2.19), hypoxic ischemic encephalopathy (RR = 2.46; 99 % CI 1.47, 4.12) and four respiratory system subtypes (ventilatory support RR = 1.11; 99 % CI 1.01, 1.23, respiratory distress syndrome RR = 1.22; 99 % CI 1.04, 1.42, primary atelectasis respiratory failure RR = 1.32; 99 % 1.02, 1.71, and bronchio-pulmonary dysplasia RR = 1.71; 99 % CI 1.00, 2.93) (Table 2). In comparison to non-immigrants, there were three subtypes that were significantly elevated (birth weight <1500 g RR = 1.28; 99 % CI 1.09, 1.51, hypoxic ischemic encephalopathy RR = 1.89; 99 % CI 1.19, 3.00, transfusion of blood or blood products RR = 2.21; 99 % CI 2.02, 2.41) among births to refugees and another two that were significantly lower (ventilator support RR = 0.85; 99 % CI 0.78, 0.94, any intravenous fluids RR = 0.86; 99 % CI 0.75, 0.98).

Discussion

This study found that the healthy migrant effect applies to non-refugees with respect to SNM risk, but likely does not apply to refugees. Non-refugee immigrants had a 20 % lower risk of SNM compared to non-immigrants, while refugees exhibited a borderline significantly lower risk, suggesting similar SNM risk between refugees and non-immigrants. These findings are consistent with other studies which show that the healthy migrant effect does not apply to refugees with respect to perinatal health [10, 26], but are much less pronounced. Despite different outcomes being examined, the extent to which the healthy migrant does not apply to refugees in the previously published studies (much higher risks in Sub Saharan Africans) compared to the current study (borderline increased risk overall, and also among Sub Saharan African refugees) is



Model 1: Risk ratios adjusted for maternal age (15-19, 20-24, 25-29, 30-34, 35-39, 40+ years) at delivery and parity (0,1,2, ≥3 previous births).
Models 2 and 3: Unadjusted risk ratios account for maternal country of birth (random intercept).
Models 2 and 3: Adjusted risk ratios account for maternal country of birth (random intercept), and adjust for maternal age at delivery (15-19, 20-24, 25-29, 30-34, 35-39, 40+ years), parity (0,1,2, ≥3 previous births), education level (0-9 years, 10-12 years, 13+ years, trade certificate/non-university diploma, Bachelors/Masters/Doctorate), language ability (one or both of English and French, neither) and duration of residence (years) (fixed effects)
ICC=intra-class correlation coefficient; N/A=not applicable; [a] statistically significant covariance parameter estimate for country of birth

Fig. 1 Any severe neonatal morbidity (SNM) unadjusted risk ratios (RR) and adjusted risk ratios (ARR) with 95 % confidence intervals (95 % CI) comparing refugees (N = 29,755) and other immigrants (N = 230,847) to non-immigrants (N = 860,314) (Model 1), refugees to other immigrants (Model 2), non-sponsored refugees (N = 15,106) to sponsored refugees (N = 10,568) (Model 3) for singleton births from 2002 to 2010

notable. It leaves one wondering whether some selection of 'healthier' refugees to Canada (relative to the global pool of refugees) is occurring despite not being subjected to either the 'points system' or exclusion based on excessive demand of health and social services [28].

We found that refugee status among immigrants was a weak risk factor for SNM. This may be due to risk factors known to be prevalent among refugees as mentioned in the introduction, however further research is needed to understand what contributes to increased risk. Given the small point estimate, however, the difference may not merit clinical intervention.

Importantly, the findings discussed thus far show the merits of disaggregating the immigrant group into refugees and other immigrants for future immigrant health research. Despite the fact that the healthy migrant effect is a well-known phenomenon, with nuances based on duration of residence (known as the "convergence hypothesis"), little attention has been paid to whether refugees adhere to it in the same way as other immigrants.

Non-sponsored and sponsored refugees experience no difference in the risk of SNM. That is, the asylum-claim process, access to a different health care funding model and lack of formal government supports to non-sponsored refugees does not confer a greater risk of SNM. Additional analyses examining the early years of settlement revealed similar, non-significant results.

Lastly, several SNM subtypes were significantly elevated for refugees with many indicating ≥60 % higher risk. This indicates that, despite being rare outcomes, these findings may be clinically important and merit further detailed study.

Strengths and Limitations

This study has limitations. There is some misclassification of the non-immigrant group, however generous estimates of 10 % misclassification suggest that corrected results strengthen the effects. The overall risk of SNM in

Table 2 Severe neonatal morbidity (SNM) subtypes (in descending order of risk among refugees), % of births with SNM subtype (n, number of cases) and unadjusted risk ratios (RR) with 99 % confidence intervals (99 % CI) comparing (1) refugees to other immigrants and (2) refugees to non-immigrants

SNM subtype	% of all births (n cases)			Unadjusted RR (99 % CI)	
	Refugees (n = 29,765)	Other Immigrants (n = 230,914)	Non-Immigrants (n = 860,617)	(1) Refugees versus Other Immigrants	(2) Refugees versus non-immigrants
Ventilatory support[a]	2.60 (774)	2.34 (5400)	3.05 (26,214)	1.11 (1.01–1.23)	0.85 (0.78–0.94)
Any intravenous fluids[a]	1.63 (486)	1.34 (3084)	1.50 (12,934)	1.22 (1.08–1.39)	1.09 (0.97–1.22)
Sepsis/septicaemia	1.25 (372)	1.18 (2724)	1.36 (11,726)	1.01 (0.88–1.16)	0.86 (0.75–0.98)
Respiratory distress syndrome	1.03 (307)	0.85 (1958)	1.13 (9713)	1.22 (1.04–1.42)	0.91 (0.79–1.06)
Gestational age < 32 weeks	0.94 (280)	0.82 (1896)	0.82 (7015)	1.15 (0.97–1.35)	1.15 (0.99–1.35)
Birth weight < 1500 grams	0.86 (256)	0.78 (1801)	0.67 (5769)	1.10 (0.93–1.31)	1.28 (1.09–1.51)
Primary atelectasis respiratory failure	0.39 (116)	0.30 (683)	0.33 (2881)	1.32 (1.02–1.71)	1.16 (0.91–1.49)
Central venous or arterial catheter[a]	0.38 (112)	0.28 (655)	0.46 (3931)	1.33 (1.02–1.73)	0.82 (0.64–1.05)
Seizure	0.26 (77)	0.16 (376)	0.20 (1729)	1.59 (1.15–2.19)	1.29 (0.95–1.74)
Pneumonia	0.21 (62)	0.18 (407)	0.21 (1794)	1.20 (0.87–1.67)	1.00 (0.73–1.36)
Any body cavity surgical procedure[a]	0.19 (58)	0.21 (482)	0.25 (2125)	0.93 (0.65–1.34)	0.79 (0.56–1.11)
Birth Trauma	0.13 (40)	0.11 (246)	0.12 (1025)	1.26 (0.81–1.96)	1.13 (0.74–1.73)
Necrotising enterocolitis	0.13 (38)	0.10 (240)	0.11 (943)	1.23 (0.78–1.93)	1.17 (0.76–1.79)
Resuscitation[a]	0.12 (36)	0.13 (291)	0.13 (1117)	0.96 (0.61–1.51)	1.07 (0.69–1.66)
Hypoxic ischemic encephalopathy	0.11 (33)	0.05 (104)	0.06 (506)	2.46 (1.47–4.12)	1.89 (1.19–3.00)
Intraventricular hemorrhage (grades 2, 3, 4)	0.09 (28)	0.08 (179)	0.09 (738)	1.21 (0.72–2.05)	1.10 (0.67–1.80)
Bronchio-pulmonary dysplasia	0.09 (28)	0.05 (127)	0.12 (1069)	1.71 (1.00–2.93)	0.76 (0.46–1.24)
Pneumothorax requiring intercostal catheter	0.07 (21)	0.08 (178)	0.12 (1068)	0.92 (0.51–1.66)	0.57 (0.32–1.00)
Transfusion of blood or blood products[a]	0.03 (9)	0.02 (37)	0.01 (118)	1.89 (0.73–4.92)	2.21 (2.02–2.41)
Cerebral infarction	0.02 (6)	0.01 (34)	0.02 (141)	1.37 (0.44–4.29)	1.23 (0.42–3.61)
Periventricular leukomalacia	[b] ([b])	0.02 (38)	0.02 (180)	[c]	[c]

[a] Interventions

[b] Suppressed due to counts ≤5

[c] Suppressed due to residual disclosure

the singleton live birth population (4.8 %) indicates that the outcome is quite common and suggests some SNM subtypes may not represent severe neonatal conditions. Further, refugee sponsorship status may affect other perinatal health outcomes that were not examined in this study. Health behaviour data were unavailable and given that immigrant mothers in Canada are more likely to exhibit healthy behaviours compared to Canadian-born women [25] this may explain the lower risk of SNM among non-refugees compared to non-immigrants. Although, not a limitation, we chose not to control for country of birth in objectives 2 and 3 since sensitivity analyses with 1:1 matching on country of birth did not change the interpretation.

A major strength of our work is the use of large population-based databases which included a diverse immigrant population. Refugee status, refugee sponsorship status and country of birth were based on official immigration records rather than self-report. To our knowledge this is the first population-based study to examine severe neonatal morbidities among refugees in a developed country.

Conclusion

Infants born to refugee women had similar risk of SNM compared to non-immigrants while non-refugee immigrants had lower risk. This suggests that the healthy

migrant effect applies to non-refugees but likely does not apply to refugees. Refugee status was a weak risk factor for SNM and is likely not a clinically relevant indicator. Differences in the immigration process, access to health care and other government supports between non-sponsored and sponsored refugees did not impact SNM. Substantially elevated risks of several SNM subtypes warrants further detailed investigation.

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Compliance with ethical standards

Conflict of interest The authors declare that we have no conflict of interest.

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