Variations in Early and Intermediate Neonatal Outcomes for Inborn Infants Admitted to a Canadian NICU and Born of Hypertensive Pregnancies

Megan A. Hayter, BSc[1], Lauren Anderson, BSc[2], Jennifer Claydon, BSc[2], Laura A. Magee, MD, FRCPC, MSc[1,2,3], Robert M. Liston, MBChB, FRCSC[1,2], Shoo K. Lee, MD, PhD, FRCPC[2,4], Peter von Dadelszen, MBChB, DPhil, FRCSC[1,2], and the Canadian Neonatal Network

[1]Department of Obstetrics and Gynaecology, University of British Columbia, Vancouver BC

[2]Centre for Healthcare Innovation and Improvement, University of British Columbia, Vancouver BC

[3]Department of Medicine, University of British Columbia, Vancouver BC

[4]Department of Paediatrics, University of British Columbia, Vancouver BC

Abstract

Objective: To determine whether neonatal intensive care unit (NICU) outcomes vary by centre for inborn neonates of hypertensive pregnancies and, if so, whether that variation might be related to between-centre variations in obstetric practice.

Methods: The study comprised a prospective cohort of 13 505 singleton neonates admitted to 17 Canadian NICUs. Adjusting for potential confounders, we used multivariate regression to analyze the relation between centre of delivery and 6 dependent variables: (1) Apgar score < 7 at 5 minutes; (2) Score of Neonatal Acute Physiology-II (SNAP-II) score ≥ 10; (3) neonatal death; (4) neonatal death or morbidity (owing to bronchopulmonary dysplasia [BPD], intraventricular hemorrhage [IVH], necrotizing enterocolitis [NEC], persistent ductus arteriosus [PDA], or periventricular leukomalacia [PVL]); (5) BPD alone; and (6) major neonatal morbidity (that is, at least one of IVH, PVL, NEC, or PDA). NICU practices known to influence these outcomes were included in the modelling for neonatal death and neonatal morbidity. In a sensitivity analysis for practice variation, antenatal steroid exposure was both included and excluded in each regression.

Results: For 5 of the 6 dependent variables, we identified between-centre variation that was not explained solely by variation in antenatal corticosteroid use. Adjusted odds ratios varied from 0.11 to 5.6 (the reference centre was the median rate of the adverse outcome).

Conclusions: In the pregnancy hypertension setting, between-centre variations in practice are associated with variations in neonatal physiology and survival. For infants admitted to NICU, the obstetric management of hypertensive pregnancies appears to have an effect on both short- and medium-term neonatal outcomes, even after correction for NICU management.

Key Words: Hypertension, pregnancy, preeclampsia, neonatal outcomes, variations

Competing interests: None declared.

Received on July 20, 2004

Accepted on November 29, 2004

Résumé

Objectif : Déterminer si les issues obtenues en unité néonatale des soins intensifs (UNSI) varient selon le centre en ce qui concerne les nouveau-nés internes issus de grossesses avec hypertension et, le cas échéant, s'il est possible que la variation en question soit associée aux variations constatées d'un centre à l'autre en matière de pratique obstétricale.

Méthodes : L'étude portait sur une cohorte prospective de 13 505 nouveau-nés simples admis au sein de 17 UNSI canadiennes. Après avoir neutralisé les effets des facteurs parasites potentiels, nous avons fait appel à une régression multivariée pour analyser la relation entre le centre où s'est déroulé l'accouchement et les six variables dépendantes suivantes : (1) indice d'Apgar < 7 à 5 minutes, (2) indice *Score of Neonatal Acute Physiology-II* (SNAP-II) = 10, (3) décès néonatal, (4) décès ou morbidité néonatale (attribuable à une dysplasie bronchopulmonaire [DBP], une hémorragie intraventriculaire [HIV], une entérocolite nécrosante [ECN], une persistance du canal artériel [PCA] ou une leucomalacie périventriculaire [LPV]), (5) DBP seule, et (6) morbidité néonatale grave (c.-à-d. la présence d'au moins une des pathologies suivantes : HIV, LPV, ECN ou PCA). Les pratiques d'UNSI dont la capacité à influencer ces issues est connue ont été intégrées à la modélisation de la mortalité et de la morbidité néonatales. Dans le cadre d'une analyse de sensibilité visant les variations quant à la pratique, l'exposition prénatale aux stéroïdes a été à la fois incluse et exclue pour chacune des régressions.

Résultats : Pour cinq des six variables dépendantes, nous avons constaté une variation d'un centre à l'autre n'étant pas uniquement attribuable à la variation du recours prénatal aux corticostéroïdes. Les rapports de cotes normalisés variaient de 0,11 à 5,6 (le centre de référence représentait le taux médian de l'issue indésirable).

Conclusions : Dans le cas des grossesses avec hypertension, les variations d'un centre à l'autre quant à la pratique sont associées à des variations de la physiologie et de la survie néonatale. Pour les

nouveau-nés admis en UNSI, la prise en charge obstétricale des grossesses avec hypertension semble avoir un effet tant sur les issues néonatales à court et à moyen termes, même après la neutralisation des effets de la gestion des UNSI.

J Obstet Gynaecol Can 2005;27(1):25-32

INTRODUCTION

Hypertensive disorders of pregnancy are a leading cause of maternal and neonatal morbidity and mortality,[1–3] complicating up to 10% of pregnancies. Hypertension in pregnancy refers to a broad spectrum of conditions[4–6] ranging from preexisting hypertension or mild gestational (pregnancy-induced) hypertension to severe preeclampsia (gestational hypertension with proteinuria), gestational hypertension without proteinuria, eclampsia, HELLP (hemolysis, elevated liver enzymes, and low platelets) syndrome,[7] and multiorgan failure.[8] One commonality exists among all these conditions—maternal and perinatal risk is increased—although the magnitude of this risk varies by subtype of hypertension.

In the management of preeclampsia, we know that between-centre [9,10] and interindividual [11,12] practice variations exist and that these can affect maternal and perinatal outcomes.[10]

The Canadian Neonatal Network Database (CNND) has identified neonatal intensive care unit (NICU) practices that are associated with improved neonatal outcomes.[13–20] For infants admitted to NICU following hypertensive pregnancies, our hypothesis was that we could identify between-centre variations in neonatal outcomes that are independent of case-mix (by adjusting for perinatal variables known to be predictive of neonatal outcomes) and neonatal practice (by adjusting for neonatal practice variations known to influence the neonatal outcomes of interest).

METHODS

We used the CNND, which contains data related to neonates admitted to 17 tertiary Canadian NICUs between January 8, 1996, and October 31, 1997, to examine the relation between maternal hypertension and neonatal outcomes. These data represent all admissions to Canadian NICUs during the study period.

The CNND does not distinguish between preexisting hypertension, pregnancy-associated hypertension (mild or severe), preeclampsia, or eclampsia; therefore, all mothers were categorically divided according to the presence or absence of hypertension across NICUs. From previous maternal chart review, we know that approximately 90% of these women had gestational hypertension, with or without proteinuria.[21] Infants had to have survived until NICU admission for inclusion in the CNND. Thus we did not record the details of stillbirths and deaths during initial resuscitation in the delivery suite.

Analysis was performed on inborn neonates born to hypertensive mothers by centre (Table 1). We excluded outborn infants from the analysis because our primary question related to variations in obstetric management within tertiary obstetric centres. It has been identified that inborn infants generally fare better than outborn infants.[14,17] We used multivariate regression analysis to examine the relation between neonates born to hypertensive mothers by centre of delivery with respect to 6 dependent variables: (1) Apgar score < 7 at 5 minutes (condition of the baby at birth), (2) neonatal illness severity as measured by Score of Neonatal Acute Physiology-II (SNAP-II) score ≥ 10 (condition of the baby in the first 12 hours of life), (3) neonatal death, (4) neonatal death and morbidity, (5) bronchopulmonary dysplasia (BPD) at 36 weeks' corrected gestational age, and (6) severe neonatal morbidity.

Severe morbidity was defined as the development of one or more of intraventricular hemorrhage (IVH), periventricular leukomalacia (PVL), necrotizing enterocolitis (NEC), or persistent ductus arteriosus (PDA). We separated BPD from this combined outcome because the NICU practices associated with variations in this outcome differ from the other 4 outcomes, which could be combined.

For Apgar and SNAP-II scores, the analyses were adjusted for potential confounders (maternal age, gestational age, sex, Caesarean delivery, and breech delivery). In the analyses for neonatal death and neonatal morbidity, in addition to the confounders listed above, we included known NICU practice confounders in the regression analyses: vasopressor use, surfactant use, ≥ 20 days on ventilation, and ≥ 25 days on supplementary oxygen. We both included and excluded a sensitivity analysis for practice variation antenatal steroid exposure in all regression modelling.

RESULTS

Of the 14 331 inborn infants admitted to the participating NICUs, 1928 were delivered of mothers with hypertension. As stated, we estimated that 90% of these women had gestational hypertension, with or without proteinuria.[21] Sites A, N, and I were excluded from the regression analysis; sites A and N had no inborn infants, while site I had only 3 inborn infants, none of whom were born to hypertensive mothers.

Table 1 describes the characteristics of neonates born to hypertensive mothers per site. Small-for-gestational age was defined as a birth weight less than the tenth percentile for gestational age according to the British Columbia Provincial Growth Chart.[22]

Table 1. Characteristics of neonatal population born to hypertensive mothers

Site	SGA, %	GA range (weeks) at delivery, %				5-minute	Range of SNAP-II score, %		
		≤ 27	28–33	34–37	≥ 38	Apgar < 7, %	1–9	10–19	20
B	13.4	9.4	34.7	47.0	8.9	9.9	23.1	14.4	17.8
C	7.3	4.9	19.2	57.1	18.8	16.3	14.3	5.7	9.0
D	8.8	5.0	30.0	49.4	15.6	20.1	21.3	15.6	13.1
E	15.0	10.2	42.5	41.9	5.4	16.2	21.0	18.1	9.0
F	8.8	5.1	12.4	68.6	13.9	9.5	9.5	8.0	3.6
G	8.4	9.0	32.6	42.7	15.7	16.9	20.0	15.2	10.7
H	16.7	9.5	29.8	46.4	14.3	11.9	22.6	9.5	7.1
J	15.0	0.0	37.8	55.6	6.7	8.9	17.8	20.9	6.7
K	13.8	17.1	46.3	33.3	3.3	11.5	24.4	14.8	14.6
L	6.1	2.4	14.6	63.4	19.5	13.8	13.4	17.1	3.7
M	5.1	0.0	27.1	59.3	13.6	13.8	10.3	8.5	8.5
O	9.3	11.4	40.0	45.7	2.9	6.4	32.9	27.1	15.0
P	6.4	0.0	12.8	68.1	19.1	4.3	19.1	0.0	2.1
Q	10.4	4.2	18.5	47.5	29.8	8.9	15.4	8.1	8.5

GA: gestational age; SGA: small-for-gestational age (birth weight <10th centile); SNAP-II: score of neonatal acute physiology-II.

Table 2. Maternal hypertensive population

Site	Number of women with hypertension	NICU admissions related to maternal hypertension, %	NICU deaths in each site related to a history of maternal hypertension, %
B	202	14.4	4.0
C	245	14.3	0.8
D	160	14.5	1.3
E	167	14.8	6.0
F	137	14.2	1.8
G	178	15.7	3.4
H	84	13.1	6.0
J	45	12.1	0.0
K	123	12.6	3.3
L	82	8.5	3.7
M	59	12.1	0.0
O	140	14.6	0.7
P	47	13.6	0.0
Q	259	19.8	1.5

NICU: neonatal intensive care unit.

Table 2 shows that there is no apparent relation between the incidence of hypertensive mothers and the incidence of neonatal death. For example, 8.5% of site L's maternal population was hypertensive, and their neonatal mortality rate was 3.7 %. Conversely, 19.8% of site Q's maternal population was hypertensive, yet the neonatal mortality rate was only 15%.

Tables 3 to 8 compare the odds ratios (ORs) and 95% confidence intervals (CIs) for the relevant neonatal outcomes across sites with and without adjustment for antenatal corticosteroid use. Table 3 shows that there was a significant variation in neonatal outcome across NICUs, with site D and H outperforming sites Q, L, and O with respect to Apgar score < 7 at 5 minutes. For centre O, adjusting for

Table 3. Apgar score < 7 at 5 minutes by centre with and without adjustment for antenatal corticosteroid use

Site	Adjusted for AN steroid use			Unadjusted for AN steroid use		
	Adjusted OR*	95% CI	*P*	Adjusted OR*	95% CI	*P*
D	0.64	0.49–0.84	0.001	0.64	0.49–0.84	0.001
H	0.71	0.52–0.97	0.031	0.71	0.52–0.97	0.029
C	0.90	0.70–1.16	ns	0.89	0.69–1.15	ns
G	0.99	0.74–1.31	ns	0.98	0.74–1.30	ns
P	1.02	0.64–1.61	ns	0.97	0.61–1.54	ns
E	1.03	0.78–1.36	ns	1.02	0.64–1.35	ns
B	1.10	0.83–1.46	ns	1.10	0.83–1.46	ns
M	1.12	0.73–1.70	ns	1.11	0.73–1.68	ns
J	1.12	0.738–1.70	ns	1.11	0.73–1.68	ns
K	1.33	0.97–1.83	ns	1.30	0.95–1.79	ns
Q	1.47	1.08–2.00	0.014	1.48	1.09–2.01	0.013
L	1.71	1.23–2.37	0.002	1.70	1.22–2.36	0.002
O	1.95	1.39–2.74	< 0.001	1.62	1.18–2.22	0.003

Centre F is the reference site.

OR: odds ratio; AN: antenatal; CI: confidence interval; ns: not significant.

*Adjusted for maternal age, gestational age, male sex, Caesarean delivery, and breech delivery.

Table 4. SNAP-II ≥ 10 by centre with and without adjustment for antenatal corticosteroid use

Site	Adjusted for AN steroid use			Unadjusted for AN steroid use		
	Adjusted OR*	95% CI	*P*	Adjusted OR*	95% CI	*P*
O	0.55	0.40–0.75	< 0.001	0.45	0.36–0.55	< 0.001
H	0.64	0.46–0.89	0.008	0.61	0.48–0.78	< 0.001
D	0.66	0.49–0.90	0.008	0.64	0.52–0.78	< 0.001
B	0.67	0.50–0.91	0.010	0.65	0.53–0.80	< 0.001
E	0.88	0.65–1.20	ns	0.84	0.68–1.04	ns
F	1.03	0.74–1.42	ns	0.99	0.78–1.26	ns
G	1.04	0.76–1.42	ns	0.95	0.70–1.30	ns
L	1.06	0.77–1.45	ns	1.02	0.81–1.28	ns
M	1.06	0.72– .56	ns	1.02	0.74–1.34	ns
K	1.19	0.85–1.65	ns	1.12	0.88–1.43	ns
C	1.30	0.97–1.75	ns	1.25	1.02–1.53	0.028
Q	1.32	0.96–1.80	ns	1.27	1.01–1.59	0.038
P	2.05	1.25–3.36	0.004	1.90	1.23–2.96	0.004

Centre J is the reference site.

OR: odds ratio; AN: antenatal; CI: confidence interval; ns: not significant.

*Adjusted for maternal age, gestational age, male sex, Caesarean delivery, and breech delivery.

Table 5. Neonatal death by centre with and without adjustment for antenatal corticosteroid use

Site	Adjusted for AN steroid use		Unadjusted for AN steroid use	
	Adjusted OR*	95% CI	Adjusted OR*	95% CI
L	0.39	0.09–1.80	0.41	0.90–1.86
H	0.64	0.17–2.48	0.68	0.18–2.64
E	0.76	0.24–2.42	0.74	0.24–2.35
B	0.98	0.29–3.28	1.08	0.33–3.50
F	1.29	0.23–7.20	1.35	0.24–7.60
Q	1.88	0.47–7.54	2.05	0.51–8.16
D	2.10	0.38–11.43	2.25	0.42–12.16
C	2.96	0.55–15.85	3.25	0.61–17.21
K	3.44	0.62–18.97	2.32	0.57–9.46
O	5.25	0.56–49.75	7.87	0.87–71.28

Centre G is the reference site.

OR: odds ratio; AN: antenatal; CI: confidence interval.

*Adjusted for gestational age and small-for-gestational age (birth weight <10th centile).
*The centres excluded from presentation are those found to be uniformative for the outcome of interest.

Table 6. Neonatal death or morbidity* by centre with and without adjustment for antenatal corticosteroid use

Site	Adjusted for AN steroid use			Unadjusted for AN steroid use		
	Adjusted OR**	95% CI	*P*	Adjusted OR**	95% CI	*P*
L	0.44	0.31–0.61	< 0.001	0.44	0.32–0.60	< 0.001
H	0.64	0.46–0.88	0.007	0.64	0.46–0.88	0.007
D	0.71	0.52–0.97	0.032	0.71	0.52–0.97	0.031
P	0.87	0.44–1.76	ns	0.75	0.38–1.49	ns
G	0.93	0.69–1.25	ns	0.92	0.68–1.25	ns
F	1.02	0.71–1.47	ns	1.02	0.71–1.47	ns
C	1.03	0.77–1.37	ns	1.01	0.76–1.35	ns
E	1.08	0.81–1.44	ns	1.06	0.80–1.42	ns
Q	1.22	0.84–1.78	ns	1.23	0.84–1.79	ns
K	1.24	0.90–1.70	ns	1.19	0.87–1.63	ns
O	1.36	0.99–1.87	ns	1.13	0.84–1.53	ns
J	1.63	0.93–2.84	ns	1.60	0.92–2.80	ns
M	2.84	1.31–6.16	0.008	2.73	1.26–5.80	0.011

Centre B is the reference site.

OR: odds ratio; AN: antenatal; CI: confidence interval; ns: not significant.

*Bronchopulmonary dysplasia at 36 weeks' corrected gestational age, intraventricular hemorrhage, necrotizing enterocolitis, persistent ductus arteriosus, and (or) periventricular leukomalacia.

**Adjusted for gestational age, birth weight, and male sex.

steroid use overestimated the adjusted OR for having a neonate with a low Apgar score at 5 minutes.

When adjusted for steroid exposure, a SNAP-II score ≥ 10 (worse neonatal physiology) was significantly more likely to occur at site P than at sites O, H, D, and B (Table 4). Again, in centre O, adjusting for steroid use overestimated the adjusted odds for having a neonate in poor condition during the first 12 hours of life. For sites C and Q, adjusting for steroid use disguised significantly higher SNAP-II scores in those centres (Table 4).

Table 7. Bronchopulmonary dysplasia (BPD) at 36 weeks' corrected gestational age by centre with adjustment for neonatal practice variations known to influence the incidence of BPD*

Site	Adjusted for AN steroid use			Unadjusted for AN steroid use		
	Adjusted OR	95% CI	*P*	Adjusted OR	95% CI	*P*
L	0.11	0.03–0.48	0.003	0.11	0.03–0.49	0.003
M	0.39	0.06–2.52	ns	0.41	0.06–2.70	ns
F	0.50	0.11–2.28	ns	0.50	0.11–2.27	ns
H	0.53	0.12–2.34	ns	0.51	0.12–2.24	ns
D	0.47	0.15–1.52	ns	0.45	0.14–1.42	ns
C	0.59	0.19–1.88	ns	0.61	0.19–1.91	ns
G	1.40	0.44–4.44	ns	1.28	0.41–4.00	ns
Q	0.66	0.19–2.23	ns	0.81	0.24–2.72	ns
B	0.88	0.31–2.54	ns	1.01	0.36–2.82	ns
O	0.84	0.24–2.92	ns	1.19	0.37–3.81	ns
P	2.24	0.12–43.29	ns	2.36	0.12–47.24	ns
K	2.83	0.88–9.12	ns	2.75	0.88–8.53	ns
J	2.92	0.20–43.50	ns	1.69	0.17–16.80	ns

Centre E is the reference site.

OR: odds ratio; AN: antenatal; CI: confidence interval; ns: not significant.

*Adjusted for gestational age, multiple birth, small-for-gestational age (birth weight < 10th centile), surfactant use, and 25 days on supplementary oxygen.

Table 8. Major neonatal morbidity (at least one of IVH, PVL, NEC, or PDA) by centre with adjustment for neonatal practice variations known to influence the outcome*

Site	Adjusted for AN steroid use			Unadjusted for AN steroid use		
	Adjusted OR	95% CI	*P*	Adjusted OR	95% CI	*P*
L	0.18	0.07–0.48	< 0.001	0.18	0.07–0.48	< 0.001
P	0.51	0.12–2.13	ns	0.60	0.17–2.15	ns
F	0.53	0.21–1.32	ns	0.52	0.21–1.30	ns
E	1.37	0.63–3.01	ns	1.38	0.63–3.02	ns
C	1.38	0.62–3 .07	ns	1.34	0.60–2.95	ns
O	1.97	0.81–4.79	ns	1.59	0.69–3.65	ns
B	2.27	1.01– 5.13	0.049	2.26	0.99–5.10	0.050
G	2.58	1.05–6.31	0.039	2.60	1.08–6.28	0.034
Q	2.59	1.06–6.32	0.036	2.61	1.07–6.38	0.035
K	3.21	1.25–8.23	0.015	2.74	1.12–6.71	0.027
H	5.64	1.39–22.84	0.015	5.64	1.40–22.81	0.015

Centre D is the reference site.

OR: odds ratio; AN: antenatal; CI: confidence interval; IVH: intraventricular hemorrhage; NEC: necrotizing enterocolitis; PDA: persistent ductus arteriosus; PVL: periventricular leukomalacia; ns: not significant.

*Adjusted for gestational age, male sex, vasopressor use, surfactant use, and 20 days on ventiltation.
*The centres excluded from presentation are those found to be uniformative for the outcome of interest.

For neonatal death, following adjustment for both pregnancy and NICU practice variables, there were no centres whose outcome varied significantly from the reference site (Table 5). In this analysis, adjustment for steroid exposure did not significantly change the analyses.

For neonatal death and morbidity (resulting from at least one of BPD, IVH, PVL, NEC, or PDA), sites L, H, and D outperformed the reference site, while site M underperformed (Table 6). Adjustment for steroid exposure did not significantly change the analyses.

For BPD (following adjustment for both pregnancy and NICU practice variables), site L had significantly fewer cases (Table 7). Adjustment for steroid exposure did not significantly change the analyses.

Major neonatal morbidity (owing to at least one of IVH, PVL, NEC, or PDA) was more likely to occur at sites B, G, Q, K, and H than at site L (Table 8). For site K, adjusting for steroid use overestimated the adjusted OR for a neonate's developing one or more of these significant adverse neonatal outcomes.

DISCUSSION

The current study demonstrates that there are variations in NICU outcomes among Canadian perinatal centres for babies admitted following a hypertensive pregnancy. This is so even after adjustment for risk factors and practice variations known to have an effect on the neonatal outcomes examined. Therefore, we feel that these variations in outcome largely reflect obstetric management. It has been identified that between-centre practice variations exist [9,10] and that these affect maternal and perinatal outcomes in preeclampsia pregnancies presenting remote from term.[10]

While the use of antenatal steroids had a discernible effect in at least one centre for 3 of the 6 outcomes, the persistent between-centre variation, when antenatal steroid use is included in the regression models, implies that other obstetric practice variations affect early- and medium-term neonatal outcomes.

Steroid use had a discernible effect on neonatal outcomes that was identifiable as early as the resuscitation phase of management (via Apgar scores). These data support our previous findings pertaining to the use of antenatal steroids for fetal lung maturation for premature infants admitted to Canadian NICUs, irrespective of cause of delivery.[16]

Adjusting for antenatal steroid use masked higher SNAP-II scores in 2 centres (centres C and Q, Table 4). The significant difference in SNAP-II scores in these centres can be largely attributed to lower antenatal steroid use during the study period. It is possible that the improved outcomes associated with steroid use may be surrogates for the implementation of other evidence-based practices. A previous study using the CNND also demonstrated large differences in the use of antenatal corticosteroids,[16] despite established evidence of their beneficial effect on neonatal outcome.[23,24]

By using the analytical approach that adjusted for gestational age at delivery, we might have overcorrected for some centres, because that adjustment tends to flatter centres that employ a "stabilize and deliver" approach rather than "expectant management" remote from term. Those centres with policies of stabilizing and delivery will deliver infants at lower gestational ages; however, those infants will fare worse in terms of adverse perinatal outcomes.[10,25–28] Despite this inherent bias in the analysis, we adjusted for gestational age at delivery as a surrogate for gestational age on admission or at diagnosis, as those data were not available in the CNND.

Prior studies have demonstrated variations in neonatal outcome among Canadian NICUs.[13,29] Some of these variations can be attributed to variation in NICU care. Other than antenatal steroid use, these studies have not accounted for the influence and role of antenatal management in optimizing neonatal outcomes. In this study, we corrected for case-mix, antenatal corticosteroid use, and, where relevant, NICU practices associated with adverse neonatal outcome. By using this approach, we have been able to show that there were significant between-centre variations in neonatal outcomes. Therefore, these data support a direct relation between antenatal care and neonatal outcome, independent of the patterns of neonatal care.

Nevertheless, this study has several limitations. First, we did not subdivide the hypertensive disorders of pregnancy into either preexisting and pregnancy-specific disorders or mild and severe disorders. Second, the diagnosis of pregnancy hypertension was not confirmed by independent chart review. Third, other than the use of antenatal steroids and the mode of delivery, no obstetric interventions were recorded in the CNND. Fourth, maternal outcomes were similarly not recorded—this is important in a condition where maternal and fetal priorities can be in conflict.[10] Fifth, a low Apgar score at 5 minutes is a relatively poor predictor of neonatal outcome in isolation (by investigating both SNAP score and neonatal outcomes, we did not investigate this surrogate). Sixth, the database did not permit exclusion of steroid exposure more than 14 days prior to delivery, but as stated, steroid use may have acted as a surrogate for other evidence-based practices.

Therefore, these data support the need to establish a national network of perinatal centres to identify obstetric practices associated with improved perinatal (including antenatal) outcomes and to collect data on maternal outcomes (and practices associated with them).

CONCLUSION

In the setting of pregnancy hypertension, between-centre variations in practice are associated with variations in neonatal physiology, survival, and quality of survival. Therefore, the obstetric management of hypertensive pregnancies may affect both short- and medium-term neonatal outcomes for infants admitted to NICU.

FUNDING AND SUPPORT

Shoo Lee is an MRC (Canada) scholar, Laura Magee an MSFHR scholar, and Peter von Dadelszen a BCRICWH investigator.

Appendix: Members of the Canadian Neonatal Network.

Shoo K. Lee, Coordinator, Canadian Neonatal Network, Vancouver, BC. Network members: Wayne Andrews, Charles A. Janeway Child Health Centre, St John's, NL; Ranjit Baboolal, North York Hospital, Toronto, ON; Jill Boulton, St Joseph's Health Centre, London, ON (previously at Mount Sinai Hospital, Toronto, ON); David Brabyn, Royal Columbian Hospital, New Westminster, BC; David S.C. Lee, St Joseph's Health Centre, London, ON; Derek Matthew, Victoria General Hospital, Victoria, BC; Douglas D. McMillan, Foothill's Hospital, Calgary, AB; Christine Newman, Hospital for Sick Children, Toronto, ON; Arne Ohlsson, Mount Sinai Hospital, Toronto, ON (formerly at Women's College Hospital, Toronto, ON); Abraham Peliowski, Royal Alexandra Hospital, Edmonton, AB; Margaret Pendray, Children's & Women's Health Centre of British Columbia, Vancouver, BC; Koravangattu Sankaran, Royal University Hospital, Saskatoon, SK; Barbara Schmidt, Hamilton Health Sciences Corporation, Hamilton, ON; Mary Seshia, Health Sciences Centre, Winnipeg, MB; Anne Synnes, Children's and Women's Health Centre of British Columbia, Vancouver, BC (formerly at Montreal Children's Hospital, Montreal, QC); Paul Thiessen, Children's & Women's Health Centre of British Columbia, Vancouver, BC; Robin Walker, Children's Hospital of Eastern Ontario and The Ottawa Hospital-General Campus, Ottawa, ON; Robin Whyte, IWK-Grace Health Centre for Women, Children and Families, Halifax, NS. Staff members, Canadian Neonatal Network Coordinating Centre: Li-Yin Chien, Joanna Sale, Herbert Chan, and Shawn Stewart, Vancouver, BC.

ACKNOWLEDGEMENTS

We acknowledge the efforts of Dr Ruth Little and of the collaborating centres in the Canadian Neonatal Network. This project was funded by grants to the Centre for Healthcare Innovation and Improvement from the BC Research Institute for Children's and Women's Health and from the Michael Smith Foundation for Health Research.

REFERENCES

1. Department of Health. Why women die. Report on confidential enquiries into maternal deaths in the United Kingdom 1994–1996. London: HMSO; 1999.
2. National Institute for Clinical Excellence. Why women die. Report on confidential enquiries into maternal deaths in the United Kingdom, 1997–1999. London: RCOG Press; 2001.
3. Pregnancy-related mortality surveillance–United States, 1987–1990. MMWR 1997;46(SS-4):17–36.
4. Report of the National High Blood Pressure Education Program Working Group on High Blood Pressure in Pregnancy. Am J Obstet Gynecol 2000;183:S1–S22.
5. Brown MA, Hague WM, Higgins J, Lowe S, McCowan L, Oats J, et al. The detection, investigation and management of hypertension in pregnancy: full consensus statement. Aust N Z J Obstet Gynaecol 2000;40:139–55.
6. Helewa ME, Burrows RF, Smith J, Williams K, Brain P, Rabkin SW. Report of the Canadian Hypertension Society Consensu Conference: 1 Definitions, evaluation and classification of hypertensive disorders in pregnancy. CMAJ 1997;157:715–25.
7. Weinstein L. Syndrome of hemolysis, elevated liver enzymes, and low platelet count: a severe consequence of hypertension in pregnancy. Am J Obstet Gynecol 1982;142:159–67.
8. von Dadelszen P, Magee LA, Marshall JC, Rotstein OD. The maternal syndrome of preeclampsia: a forme fruste of the systemic inflammatory response syndrome. Sepsis 2000;4:43–7.
9. Davis GK, Homer CS, Brown MA. Hypertension in pregnancy: do consensus statements make a difference? Aust N Z J Obstet Gynaecol 2002;42:369–73.
10. Olah KS, Redman CWG, Gee H. Management of severe, early pre-eclampsia: is conservative management justified? Eur J Obstet Gynecol Reprod Biol 1993;51:175–80.
11. Caetano M, Ornstein MP, von Dadelszen P, Hannah ME, Logan A, Gruslin A, et al. A survey of Canadian practitioners regarding the management of hypertension in pregnancy. Hypertens Pregn 2004;23(1):61–74.
12. Caetano M, Ornstein MP, von Dadelszen P, Hannah ME, Logan A, Gruslin A, et al. A survey of Canadian physicians regarding the diagnosis and evaluation of hypertension in pregnancy. Hypertens Pregn 2004;23(2):197–209.
13. Lee SK, McMillan DD, Ohlsson A, Pendray M, Synnes A, Whyte R, et al. Variations in practice and outcomes in the Canadian NICU network: 1996–1997. Pediatrics 2000;106:1070–9.
14. Chien LY, Whyte R, Aziz K, Thiessen P, Matthew D, Lee SK. Improved outcome of preterm infants when delivered in tertiary care centers. Obstet Gynecol 2001;98:247–52.
15. Chien LY, Macnab Y, Aziz K, Andrews W, McMillan DD, Lee SK. Variations in central venous catheter-related infection risks among Canadian neonatal intensive care units. Pediatr Infect Dis J 2002;21:505–11.
16. Chien LY, Ohlsson A, Seshia MM, Boulton J, Sankaran K, Lee SK. Variations in antenatal corticosteroid therapy: a persistent problem despite 30 years of evidence. Obstet Gynecol 2002;99:401–8.
17. Lee SK, McMillan DD, Ohlsson A, Boulton J, Lee DS, Ting S, et al. The benefit of preterm birth at tertiary care centers is related to gestational age. Am J Obstet Gynecol 2003;188:617–22.
18. Lee SK, Lee DS, Andrews WL, Baboolal R, Pendray M, Stewart S. Higher mortality rates among inborn infants admitted to neonatal intensive care units at night. J Pediatr 2003;143:592–7.
19. Skarsgard ED, Blair GK, Lee SK. Toward evidence-based best practices in neonatal surgical care. I. The Canadian NICU Network. J Pediatr Surg 2003;38:672–7.
20. Synnes AR, Chien LY, Peliowski A, Baboolal R, Lee SK. Variations in intraventricular hemorrhage incidence rates among Canadian neonatal intensive care units. J Pediatr 2001;138:525–31.
21. von Dadelszen P, Taylor EL, Muir JC, Stewart SD, Sherman P, Magee LA, et al. Maternal hypertension in pregnancy is associated with better neonatal outcome among babies admitted to NICU. Obstet Gynecol. In Press.
22. Whitfield M. British Columbia Provincial Growth Chart [report]. Vancouver BC: BC Children's Hospital; 1992.
23. Liggins GC, Howie RN. A controlled trial of antepartum glucocorticoid treatment for prevention of the respiratory distress syndrome in premature infants. Pediatrics 1972;50:515–25.
24. Crowley P. Promoting pulmonary maturity. In: Enkin M, Keirse JNC, Chalmers I, editors. Effective care in pregnancy and childbirth. New York: Oxford University Press; 1989.
25. Magee LA, Ornstein MP, von Dadelszen P. Fortnightly review: management of hypertension in pregnancy. BMJ 1999;318:1332–6.
26. Odendaal HJ, Pattinson RC, Bam R, Grove D, Kotze TJ. Aggressive or expectant management for patients with severe preeclampsia between 28–34 weeks' gestation: a randomized controlled trial. Obstet Gynecol 1990;76:1070–5.
27. Sibai BM, Mercer BM, Schiff E, Friedman SA. Aggressive versus expectant management of severe preeclampsia at 28 to 32 weeks' gestation: a randomized controlled trial. Am J Obstet Gynecol 1994;171:818–22.
28. von Dadelszen P, Magee LA, Lee SK, Stewart SD, Simone C, Koren G, et al. Activated protein C in normal human pregnancy and pregnancies complicated by severe preeclampsia: a therapeutic opportunity? Crit Care Med 2002;30:1883–92.
29. Sankaran K, Chien LY, Walker R, Seshia M, Ohlsson A. Variations in mortality rates among Canadian neonatal intensive care units. CMAJ 2002;166:173–8.