Original Article

The effect of mode of delivery and anaesthesia on neonatal blood pressure

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Background: Many factors may effect blood pressure (BP) in the early neonatal period, including mode of delivery and anaesthesia, on which there is little reported.

Aims: To determine whether the mode of delivery, anaesthesia and maternal age have an effect on neonatal BP in the first three days of life.

Methods: Healthy, term neonates from August 2003–2005 were enrolled in the study. Infants of mothers with hypertension of any cause, diabetes of any cause, illicit substance use, congenital or chromosomal anomaly, and admission to the neonatal intensive care unit were excluded. Information on maternal age, duration of labour, mode of delivery, anaesthesia and postdelivery analgesic use was obtained. Blood pressure readings from day one to three of life were analysed.

Results: Four hundred and six infants were enrolled into the study. Both spinal anaesthesia and elective caesarean delivery were associated with a lower systolic BP reading on day one, but not on day two or three ($P = 0.004$ and $P = 0.023$, respectively). Multivariate analysis indicated that spinal anaesthesia was the most significant variable for a lower systolic BP on day one ($P = 0.022$). There was no correlation between maternal age and BP on day one to three.

Conclusions: Spinal anaesthesia is associated with a statistically lower systolic BP on the first day of life; the clinical significance is as yet unclear.

Key words: anaesthesia, blood pressure, delivery, neonate.

Introduction

Blood pressure (BP) in the newborn, as with the adult, is an important indicator of appropriate circulation. Factors such as maternal age have been noted to have an effect on neonatal BP.¹ Some authors have reported that healthy term neonates born by caesarean section have a lower systolic BP at the 24th hour of life and day three/four than babies born by other modes of

delivery.^{2–4} However, other authors report that mode of delivery does not effect neonatal BP on day one or four/five.⁵ The difference in reported results on day one may be the result of methodological differences related to population size and heterogeneous sample populations.

The effect of anaesthesia on neonatal BP is not clear. Mattingly *et al.* reported that the mode of anaesthesia did not adversely effect the neonate, if the anaesthetic was properly administered.⁶ However, as anaesthesia is required for caesarean section, it is plausible to hypothesise that the anaesthesia itself and its mode of delivery may be a confounding factor in BP in neonates born by caesarean section delivery. Studies of mode of anaesthesia and neonatal well-being have identified that mode of anaesthesia effects Apgar scores, pH balance and left ventricular ejection

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Received 19 August 2007; accepted 17 December 2007.

time of the neonate.^{7,8} In contrast, one study has reported that neonatal BP is not effected by the anaesthetic technique used.⁹ However, the study had a small population size ($N = 24$) and did not include spinal anaesthesia in its analysis as it was not a routine technique at the time. Therefore, investigation of the effect of modes of obstetric anaesthesia and delivery on neonatal BP is warranted.

A positive association between older mothers and high neonatal systolic BP in the first three days of life has been reported.¹ This study examined a heterogeneous group of infants, including mothers with hypertension. Further investigation is warranted to determine whether this association holds without maternal confounders.

The aims of the present study were to determine in a cohort of healthy term neonates whether: mode of delivery and/or anaesthesia, or maternal age had an effect on neonatal BP in the first three days of life.

Methods

Term infants (> 36 completed weeks gestation) born between August 2003 and August 2005 were prospectively enrolled in the study. Exclusion criteria for participation in the study were: infants of mothers with hypertension of any cause, diabetes of any cause, or history of illicit substance use, infants with congenital or chromosomal anomalies, possible sepsis or admission to the neonatal intensive care unit. Ethics approval for the initial study was obtained from the local Human Research Ethics Committee. Written informed consent was gained from a parent of the infant. The local Human Research Ethics Committee and the hospital executive approved obtaining further data on length of labour, mode of delivery, anaesthesia used in delivery and postnatal analgesic use. These data were obtained from the hospital electronic medical record.

Infant demographics collected included: gestation, sex, birthweight, length, and Apgar score at one and five minutes. Mode of delivery were defined as: vaginal delivery (no instrumental assistance or caesarean section); instrumental assistance for vaginal delivery (forceps or ventouse extraction); elective caesarean section (a caesarean section with no labour); and emergency caesarean section (labour discontinued and delivery by caesarean section). Mode of anaesthesia was defined as: no regional/general anaesthesia (this also included pudendal block, intramuscular narcotics or nitrous oxide); epidural anaesthesia (anaesthesia or analgesia with epidural block +/- pethidine); spinal anaesthesia (anaesthesia or analgesia with spinal block) or general anaesthesia (anaesthesia with oxygen, nitrous

oxide, volatile anaesthetic agent, opioid, barbiturate and suxamethonium). Hyperbaric bupivacaine was used for all spinal anaesthesia and ropivacaine/bupivacaine with fentanyl for all epidural anaesthesia. Morphine and/or topical lignocaine were also used for both spinal and epidural anaesthesia.

Blood pressure measurement in the neonate

Blood pressure measurements from day one to three of life were used in this study. Blood pressure measurements on day one were taken between 12 and 24 h of life to allow for transition of fetal circulation. Measurements were taken using a BP cuff on an upper limb with the infant in a resting state. Propaq Encore 202 EL monitor smartcuf (Protocol Systems Inc, Oregon, USA), a non-invasive technology, was used. This monitor has passed the Association for Advancement of Medical Instrumentation standards for sphygmomanometers. Verification included clinical testing on human subjects that ranged from neonatal to adult demographics and involved multiple BP readings per patient over a wide range of BPs. Clinical testing utilised an intra-arterial BP reference for determination of both average error and standard deviation, and the Propaq series monitor met all requirements. An average of three readings for systolic, mean and diastolic readings per day were used for analysis.¹⁰ There were no differences in BP between day two and day three, and, as such, only day two readings are reported.¹⁰

Data analysis

Data were stored and analysed using SPSS 15.01 (SPSS Inc., Chicago, IL, USA), significance levels were set at 0.05. Figures were produced using SPSS 15.01. Kruskal–Wallis test was used to compare BP readings and mode of delivery and anaesthesia. Chi-square and ANOVA were used to examine infant demographics with mode of delivery and anaesthesia as appropriate. Bonferroni-adjusted pairwise comparisons were included. Dummy variable ordinary least squares regression was used to examine the relative significance of spinal anaesthesia and mode of delivery. Pearson correlation coefficients and scatterplots were used to examine the relationship between neonatal BP and maternal age.

Results

Four hundred and six infants were enrolled into the study. Of these, 265 (65%) were delivered vaginally;

Table 1 Infant demographics and mode of anaesthesia

Infant demographic variable	Mode of anaesthesia				P-value
	No regional/general <i>n</i> = 214	Epidural <i>n</i> = 123	Spinal <i>n</i> = 61	General <i>n</i> = 8	
Mean gestation (weeks) ($\pm$ SD)*	39.7 ($\pm$ 1.2)	39.8 ($\pm$ 1.3)	39.0 ($\pm$ 1.3)	39.1 ($\pm$ 1.1)	0.001
Bonferroni ($P < 0.05$)	$\wedge$	#	$\wedge$, #		
Mean birthweight (g) ($\pm$ SD)*	3512 ($\pm$ 466)	3613 ($\pm$ 482)	3428 ($\pm$ 485)	3412 ($\pm$ 251)	0.059
Mean length (cm) ($\pm$ SD)*	50.1 ($\pm$ 2.1)	50.5 ($\pm$ 2.1)	49.3 ($\pm$ 2.6)	49.6 ($\pm$ 1.1)	0.006
Bonferroni ($P < 0.05$)	$\wedge$	#	$\wedge$, #		
Mean Apgar 1 min ($\pm$ SD)*	8.6 ($\pm$ 1.0)	8.1 ($\pm$ 1.4)	8.6 ($\pm$ 1.2)	7.0 ($\pm$ 2.9)	< 0.0001
Bonferroni ($P < 0.05$)	$\wedge$, #	$\wedge$, Δ	Ω	#, Δ , Ω	
Mean Apgar 5 min ($\pm$ SD)*	9.0 ($\pm$ 0.3)	9.0 ($\pm$ 0.4)	9.0 ($\pm$ 0.4)	9.0 ($\pm$ 0.9)	0.904
Male sex (%)**	119 (55.6)	64 (52.0)	32 (52.5)	2 (25.0)	0.209

*ANOVA, Bonferroni-adjusted pairwise comparisons found to be significant ($P < 0.05$) are denoted by the same symbol in each row.

** χ^2 test. SD, standard deviation.

48 (12%) required instrumental assistance for vaginal delivery; 64 (16%) were delivered by elective caesarean section; and 29 (7%) required an emergency caesarean section. Two hundred and fourteen women did not require any anaesthesia for delivery (53%); 123 (30%) had an epidural anaesthesia; 61 (15%) had a spinal anaesthesia; and eight (2%) women had a general anaesthetic. Of the eight women who had a general anaesthetic, three had an epidural that then required general anaesthetic for elective caesarean delivery, and two had failed spinal anaesthetics for elective caesarean delivery. Data were available for 397 infants on day one and 232 on day two, the reduction in number due to the hospital's early discharge policy. There were no statistically significant differences in type of delivery, type of anaesthesia, birthweight, gestation, sex, Apgar scores at one and five minutes and BP on day one of life in those with and without readings available on day two of life.

Neonates in the spinal anaesthesia group had a significantly lower gestational age and length ($P = 0.001$ and 0.006 , respectively) (Table 1). The one-minute Apgar scores were significantly lower with general anaesthesia ($P < 0.0001$). Birthweight, five-minute Apgar scores and male sex were not significantly different with mode of anaesthesia (Table 1). Neonates in the elective caesarean section delivery group had a significantly lower gestation, birthweight and length ($P < 0.0001$, 0.04 and < 0.0001 , respectively)

(Table 2). One- and five-minute Apgar scores and male sex were not significantly different with mode of delivery (Table 2).

Spinal anaesthetic was associated with a lower systolic BP on day one of life, but not for mean or diastolic readings ($P = 0.004$, 0.18 and 0.57 , respectively). There were no significant differences in BP readings and mode of anaesthetic on day two of life (Table 3). Elective caesarean section was associated with a lower systolic BP reading on day one of life, but not for mean or diastolic readings ($P = 0.023$, 0.07 and 0.17 , respectively). There were no significant differences in BP readings and mode of anaesthetic on day two of life (Table 4). No differences were found for mode of delivery or anaesthetic on day three of life.

Given that both spinal anaesthetic and elective caesarean section were found to be significantly associated with a lower systolic BP on day one of life, a dummy variable ordinary least squares regression was used to examine the relative significance of spinal anaesthesia and elective caesarean section. In the model, gestation and weight were not found to be significant, nor was elective caesarean ($P = 0.64$), but spinal anaesthesia continued to be a significant factor ($P = 0.015$). There was no combined effect of type of delivery and anaesthetic on BP ($P = 0.69$).

There was no significant correlation of maternal age with systolic, mean or diastolic BP on day one

Table 2 Infant demographics and mode of delivery

Infant demographic variable	Mode of delivery				P-value
	Normal vaginal delivery <i>n</i> = 265	Instrumental <i>n</i> = 48	Elective caesarean <i>n</i> = 64	Emergency caesarean <i>n</i> = 29	
Mean gestation (weeks) ($\pm$ SD)*	39.7 ($\pm$ 1.2)	39.8 ($\pm$ 1.2)	38.9 ($\pm$ 1.2)	40.1 ($\pm$ 1.2)	< 0.0001
Bonferroni (P < 0.05)	^	#	^, #, Δ	Δ	
Mean birthweight (g) ($\pm$ SD)*	3530 ($\pm$ 469)	3507 ($\pm$ 419)	3444 ($\pm$ 481)	3745 ($\pm$ 534)	0.04
Bonferroni (P < 0.05)			^	^	
Mean length (cm) ($\pm$ SD)*	50.1 ($\pm$ 2.1)	50.7 ($\pm$ 2.1)	49.2 ($\pm$ 2.5)	51.0 ($\pm$ 1.9)	< 0.0001
	^	#	^, #, Δ	Δ	
Mean Apgar 1 min ($\pm$ SD)*	8.5 ($\pm$ 1.1)	8.0 ($\pm$ 1.6)	8.6 ($\pm$ 1.2)	8.2 ($\pm$ 1.6)	0.05
Mean Apgar 5 min ($\pm$ SD)*	9.0 ($\pm$ 0.3)	8.9 ($\pm$ 0.5)	9.1 ($\pm$ 0.4)	9.1 ($\pm$ 0.4)	0.06
Male sex (%)**	142 (53.6)	23 (47.9)	35 (54.7)	18 (62.1)	0.685

*ANOVA, Bonferroni-adjusted pairwise comparisons found to be significant (P < 0.05) are denoted by the same symbol in each row.

** χ^2 test. SD, standard deviation.

Table 3 Average neonatal blood pressure and mode of anaesthesia

Average blood pressure ($\pm$ SD)**	Mode of anaesthesia				P-value
	No regional/general	Epidural	Spinal	General	
Day one	<i>n</i> = 207	<i>n</i> = 119	<i>n</i> = 61	<i>n</i> = 8	
Systolic	66.9 ($\pm$ 7.9)	65.5 ($\pm$ 7.5)	62.9 ($\pm$ 6.1)	65.5 ($\pm$ 4.9)	0.004
Bonferroni (P < 0.05)*	^		^		
Mean	48.3 ($\pm$ 5.9)	47.5 ($\pm$ 5.8)	46.73 ($\pm$ 4.9)	46.13 ($\pm$ 3.8)	0.179
Diastolic	39.9 ($\pm$ 6.0)	39.4 ($\pm$ 5.9)	39.3 ($\pm$ 5.3)	37.6 ($\pm$ 4.4)	0.567
Day two	<i>n</i> = 124	<i>n</i> = 69	<i>n</i> = 46	<i>n</i> = 5	
Systolic	69.3 ($\pm$ 7.5)	68.9 ($\pm$ 7.9)	68.2 ($\pm$ 7.0)	67.2 ($\pm$ 11.3)	0.824
Mean	51.6 ($\pm$ 5.9)	50.8 ($\pm$ 5.4)	51.2 ($\pm$ 6.3)	49.0 ($\pm$ 10.1)	0.681
Diastolic	42.9 ($\pm$ 5.9)	42.2 ($\pm$ 4.9)	42.9 ($\pm$ 6.2)	41.6 ($\pm$ 10.2)	0.796

*ANOVA, Bonferroni-adjusted pairwise comparisons found to be significant (P < 0.05) are denoted by the same symbol in each row.

**Kruskal–Wallis test. SD, standard deviation.

(P = 0.69, 0.68, 0.41, respectively) or day two of life (P = 0.53, 0.60, 0.97, respectively) with all types of delivery and anaesthesia included. Scatterplots of systolic BP and maternal age on day one and two of life are provided in Figs 1 and 2. An analysis of vaginal deliveries alone, to exclude the potential confounders of type of delivery and

anaesthesia found no significant difference with maternal age.

Discussion

Our study has shown statistically that a lower systolic BP on day one of life in neonates is associated with

Table 4 Average neonatal blood pressure and mode of delivery

Average blood pressure ($\pm$ SD)**	Mode of delivery				P-value
	Normal vaginal delivery	Instrumental	Elective caesarean	Emergency caesarean	
Day one	<i>n</i> = 258	<i>n</i> = 47	<i>n</i> = 64	<i>n</i> = 27	
Systolic	66.8 ($\pm$ 7.9)	64.3 ($\pm$ 7.4)	63.7 ($\pm$ 6.1)	65.9 ($\pm$ 7.6)	0.023
Bonferroni ($P < 0.05$)*	$\wedge$			$\wedge$	
Mean	48.3 ($\pm$ 5.9)	46.9 ($\pm$ 5.6)	46.8 ($\pm$ 4.9)	46.3 ($\pm$ 5.1)	0.073
Diastolic	40.1 ($\pm$ 6.0)	39.3 ($\pm$ 5.9)	39.1 ($\pm$ 5.4)	37.6 ($\pm$ 5.3)	0.165
Day two	<i>n</i> = 151	<i>n</i> = 26	<i>n</i> = 48	<i>n</i> = 20	
Systolic	68.7 ($\pm$ 7.1)	71.2 ($\pm$ 10.0)	69.6 ($\pm$ 9.3)	68.3 ($\pm$ 6.8)	0.409
Mean	51.2 ($\pm$ 5.8)	52.4 ($\pm$ 5.4)	50.8 ($\pm$ 6.2)	50.8 ($\pm$ 6.2)	0.719
Diastolic	42.7 ($\pm$ 5.6)	43.5 ($\pm$ 5.6)	42.4 ($\pm$ 6.2)	42.8 ($\pm$ 7.1)	0.886

*ANOVA, Bonferroni-adjusted pairwise comparisons found to be significant ($P < 0.05$) are denoted by the same symbol in each row.

**Kruskal–Wallis test.

Figure 1 Neonatal systolic blood pressure and maternal age on day one of life. **Figure 2** Neonatal systolic blood pressure and maternal age on day two of life.

spinal anaesthesia rather than caesarean section delivery; however, this may not necessarily be clinically significant. Previous studies have suggested that caesarean delivery is associated with a lower BP, but they have not examined the role of the mode of the anaesthesia in their analysis.^{2–4} Changes in left ventricular ejection time in the neonate have also been related to effects of anaesthesia rather than mode of delivery.⁹ This study, unlike that of O'Sullivan *et al.*, has not shown any difference by the third day

of life of a lower systolic BP in neonates born by caesarean section.⁴ This finding is somewhat limited by the loss of follow up of infants (58%) from day one to two of life, because of early hospital discharge policy.¹⁰ A follow-up rate of greater than 70% would provide more power to this study. However, this study provides some of the largest data on BP in healthy term neonates in the current era of obstetric anaesthesia and BP measurement using modern oscillometric techniques.

One-minute Apgar scores of neonates delivered via caesarean section with maternal general anaesthesia were significantly lower than epidural, spinal and no regional/general anaesthesia, consistent with other reports.^{7,8} There was no significant difference in five-minute Apgar scores with mode of anaesthesia, which is similar to the findings of Kavak *et al.*¹¹

Spinal and epidural anaesthesia are now the preferred method of obstetric anaesthesia and analgesia, as they are associated with fewer neonatal adverse events.⁶ One study has reported an association with breast-feeding difficulties and increased breast-feeding cessation with epidural anaesthesia,¹² which may influence the benefits of breast-feeding including a modest decrease in systolic BP in childhood.¹³ Whether this is also observed with spinal anaesthesia is unclear.

Furthermore, maternal hypotension is a common complication of spinal and epidural anaesthesia and may have adverse effects on uteroplacental blood flow.¹⁴ The onset of hypotension is much faster and its severity is more pronounced with a spinal technique. It can be speculated that this rapid change in BP might result in the liberation of maternal mediators that may give rise to the change in systolic pressure of the neonate. Similarly, the drugs used to prevent or treat maternal hypotension may also have adverse effects on the neonate.¹⁴ The observed lower neonatal systolic BP on day one in this study is less likely to be related to the drugs administered with the neuraxial block as the amount of local anaesthetic agent and opioid is significantly greater with epidural analgesia. Data on maternal BP were not available for the purpose of this study.

Another cause of the lower systolic BP may be the increased association of fetal acidosis observed with spinal anaesthesia compared to epidural or general anaesthesia.^{8,15–17} This, however, is not a consistent finding with other authors reporting that spinal anaesthesia for elective caesarean deliveries in healthy women and term neonates does not adversely effect neonatal short-term outcomes and poses no risks to neonates.^{11,18} These studies, however, have focused on Apgar scores and umbilical cord pH. Consequently, neonatal BP may be an additional variable to measure when assessing effects of maternal anaesthesia on the neonate.

The implication of lower neonatal systolic BP on day one is unknown and may be related to the physiological changes that occur in BP during the first three days of life.¹⁹ A recent study by Morley *et al.* has found no association between BP in children (average age eight years old) born at term with their

mode of delivery.²⁰ However, the authors did not report mode of anaesthesia and BP findings in later childhood.

Our study has not shown any association between maternal age and neonatal BP. This is in contrast to the findings of Gillman *et al.*, where an increased neonatal systolic BP with greater maternal age was reported.¹ The study conducted by Gillman *et al.* involved 1056 women and their neonates in which ultrasound and Dinamap were used for neonatal BP measurement. The contrasting findings with this study may be the result of the differences in exclusion criteria for the population of women. Gillman *et al.* investigated a heterogeneous sample population, where exclusion criteria regarding maternal comorbidities such as hypertension and diabetes were not included. Even though possible confounding variables were taken into account, it is still possible that a heterogeneous population may distort results. In contrast, this study used stringent inclusion/exclusion criteria, whereby a population of healthy pregnant women and their healthy full-term neonates was investigated. This study therefore samples a homogeneous population, allowing for more valid extrapolations to similar populations.

In summary, this study suggests that spinal anaesthesia may be associated with a lower systolic BP in healthy full-term neonates on day one of life. This appears to be a short-term phenomenon, as this was no longer found on day two and three of life. Additionally, this study does not suggest that maternal age has an effect on neonatal BP. Further studies are required to evaluate the association between spinal anaesthesia and neonatal BP.

Acknowledgements

We would like to acknowledge The Canberra Hospital Private Practice Fund for financial support for equipment and personnel. We would like to thank Sandy Meskell, Centre for Newborn Care Research Nurse, for her efforts in recruitment and BP measurements.

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