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Predicting intrapartum fetal compromise using the fetal Cerebro-Umbilical ratio

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Abstract

Introduction

The aim of this study was to explore the association between the cerebro-umbilical ratio measured at 35-37 weeks and intrapartum fetal compromise.

Methods

This retrospective cross sectional study was conducted at the Mater Mothers' Hospital in Brisbane, Australia. Maternal demographics and fetal Doppler indices at 35-37 weeks gestation for 1381 women were correlated with intrapartum and neonatal outcomes.

Results

Babies born by caesarean section or instrumental delivery for fetal compromise had the lowest median cerebro-umbilical ratio 1.60 (IQR 1.22-2.08) compared to all other delivery groups (vaginal delivery, emergency delivery for failure to progress, emergency caesarean section for other reasons or elective caesarean section). The percentage of infants with a cerebro-umbilical ratio <10th centile that required emergency delivery (caesarean section or instrumental delivery) for fetal compromise was 22%, whereas only 7.3% of infants with a cerebro-umbilical ratio between the 10th-90th centile and 9.6% of infants with a cerebro-umbilical ratio > 90th centile required delivery for the same indication ($p < 0.001$). A lower cerebro-umbilical ratio was associated with an increased risk of emergency delivery for fetal compromise, OR 2.03 (95% CI 1.41-2.92), $p < 0.0001$.

Discussion

This study suggests that a low fetal cerebro-umbilical ratio measured at 35-37 weeks is associated with a greater risk of intrapartum compromise. This is a relatively simple technique which could be used to risk stratify women in diverse healthcare settings.

Key words

Cerebro-placental ratio, cerebro-umbilical ratio, C/U ratio, fetal compromise, normal growth, growth restriction, pregnancy

Introduction

Intrapartum hypoxia can develop from gradual deterioration of placental function, or from acute events such as placental abruption or cord prolapse and compression. While acute events are generally unpredictable and unpreventable, antenatal detection of chronic placental insufficiency has the potential to influence obstetric management including mode and timing of delivery thereby potentially improving perinatal outcomes.

Identifying which fetus will develop intrapartum compromise (or fetal distress) can be difficult. Protective mechanisms in the fetus usually mitigate the development of intrapartum hypoxia during labour, when uterine contractions reduce blood supply to the placenta by almost 60% [1]. These mechanisms include an increased preload and cerebral redistribution of cardiac output [2]. Some babies are at a higher risk of intrapartum compromise due to complications such as fetal growth restriction [3], however, as many as 63% of cases of intra-partum hypoxia occur in pregnancies with no antenatal risk factors [4].

We have recently shown that the cerebro-umbilical (C/U) ratio (ratio of the pulsatility index (PI) of the umbilical artery (UA) to the middle cerebral artery (MCA)), measured within 72 hours prior to delivery is predictive of intrapartum fetal compromise [5]. A low ratio (<10^{th} centile) was a risk factor for fetal compromise; conversely, a high ratio (>90^{th} centile) appeared to be protective with a negative predictive value of almost 100% [5]. In addition, umbilical venous flow is also reduced in fetuses that go on to develop intrapartum fetal compromise [6].

Whilst these results are encouraging, fetal assessment within 72 hours of delivery is logistically challenging outside of a dedicated research setting. Given the practical issues in performing an ultrasound close to labour and delivery, we wanted to ascertain if a similar relationship still held if the Doppler indices were measured some weeks remote from delivery. Therefore, the aim of this study was to assess if a low C/U ratio (<10th centile) measured at 35-37 weeks was predictive of emergency delivery for intrapartum fetal compromise.

Materials and Methods

This was a retrospective cohort study of women delivering at the Mater Mothers' Hospital in Brisbane between June 1998 and November 2013 using previous prospectively collected data from the institution's perinatal database. The Mater Mothers' Hospital is the largest maternity hospital in Queensland and a major tertiary centre. The study protocol was assessed and approved by the hospital's Human Research Ethics Committee (Reference number HREC/14/MHS/37).

All women with a singleton fetus undergoing an ultrasound scan between 35-37 weeks gestation with a UA PI <95th centile for the gestation and had no contraindications for a vaginal delivery were eligible for inclusion in this study. Gestational age was calculated from either the last menstrual period or by the earliest ultrasound examination or correlation with both. Exclusion criteria included multiple pregnancy, known genetic conditions or congenital malformations, non-cephalic presentation, ruptured membranes, absent/reversed end-diastolic flow in the UA, unknown UA PI or MCA PI or unknown mode of delivery. Indications for requesting a fetal growth and wellbeing scan at 35-37 weeks

varied, although the commonest reasons were uncertainty of fetal size or presentation on clinical examination, previous pregnancy complications or maternal anxiety. Demographic data collected included parity, maternal age, body mass index (BMI) and ethnicity (Caucasian, Asian, Indigenous (Aboriginal or Torres Strait Islander (ATSI)) or other).

The estimated fetal weight (EFW) was calculated using Hadlock's formula [7]. For all Doppler parameters, recordings were taken in the absence of fetal breathing movements. An automated tracing method was used incorporating at least 3 waveforms, and repeated 3 times to obtain a mean pulsatility index. The angle of insonation of the vessel was always kept <30 degrees. The MCA was first imaged using colour Doppler with the waveform then recorded from the proximal third of the vessel, distal to its origin at the circle of Willis. Either the right or left MCA was used depending on the quality of the waveform obtained. The UA Doppler waveforms were recorded from a free loop of cord. The C/U ratio was calculated for each patient by dividing the MCA PI by the UA PI. The primary outcome measure for this study was the occurrence of intrapartum fetal compromise (as diagnosed by the obstetric team) requiring emergency delivery (either caesarean section or instrumental delivery). Secondary outcomes included Apgar scores at 1 and 5 minutes, arterial cord blood gases if performed (arterial pH and base excess), and admission to the neonatal intensive care unit.

Given the retrospective nature of this study and the difficulty in applying a rigorous definition to the diagnosis of "fetal compromise" we chose to adopt a pragmatic approach and used the primary indication for delivery/intervention as recorded in the maternity database. We considered this definition reasonable, as the diagnosis of fetal compromise

would generally have been made on the basis of an abnormal fetal heart pattern, fetal scalp pH or fetal scalp lactate, fully accepting the limitations of this methodology in our analysis.

Infants were grouped into five categories of mode of delivery: emergency delivery (instrumental or caesarean section) for fetal compromise, spontaneous vaginal delivery, emergency delivery for failure to progress (instrumental or caesarean section), emergency caesarean section for other reasons or elective caesarean section.

The UA PI, MCA PI and C/U ratios (stratified by $<10^{th}$ centile, $\geq 10^{th}$-90^{th} centile and $\geq 90^{th}$ centile), parity, maternal age, BMI, distribution of ethnicity, gestational age at delivery, birthweight, Apgar < 7 at five minutes, cord arterial pH <7.2, base excess >8mmol/L and admission to the neonatal unit were obtained from the maternity database. Data was assessed for normality using the Shapiro-Wilk test.

All continuous variables showed a skewed distribution, and therefore the Kruskall-Wallis test or Wilcoxon Rank Sum test were used for comparisons between groups. Proportions were compared using a Chi-square test or Fisher's exact test if the expected cell frequencies were <5. Summary statistics are reported as median (IQR) unless otherwise indicated. Predictors of the need for emergency delivery for fetal compromise compared to all other modes of delivery were evaluated using logistic regression. Data was analyzed using Microsoft Excel and Stata version 13 (www.stata.com). Statistical significance was set at p=0.05. No adjustment was made for multiple comparisons [8].

Results

Demographics

Over the study period, a total of 1381 women fulfilled the entry criteria. The median maternal age was 30 (26-34) years and median body mass index (BMI) was 23 (20-27)kg/m^2. The median gestational age at ultrasound was 36+1 (35+5-36+4) weeks. The median gestational age at delivery was 38 (37-39) weeks and median birth weight was 2870 (2478-3310)g. Forty one point eight percent of the study cohort were primiparous women. The proportion of births that were either induced or augmented was 27.7% (382/1381). It was not possible to differentiate between the two categories as categorisation in the database was not specific enough to allow us to do this.

Modes of delivery

The proportion of emergency deliveries (instrumental or caesarean section) for fetal compromise was 9.0% (124/1381), spontaneous vaginal delivery (SVD) was 49.3% (681/1381), emergency delivery (instrumental or caesarean section) for failure to progress was 9.9% (137/1381), emergency caesarean section for other reasons was 8.9% (123/1381) and elective caesarean was 22.9% (316/1381).

Neonatal characteristics

Overall, Apgar scores at 5 minutes were available for 1378 infants; of these infants, 1.5% (21/1378) had an Apgar score of <7 at 5 minutes. Limited data was available for other neonatal indices. On the information available, 26% (12/46) had a cord arterial pH <7.2, 12% (3/25) had a base excess >-8 mmol/L and 55% (295/541) required admission to the neonatal unit. The only neonatal outcome that differed ($p<0.001$) across delivery groups was admission to the nursery, in which the group of infants that required emergency delivery for fetal compromise had the highest proportion of admissions (43.5% (54/124)) (Table 1).

Umbilical Artery Pulsatility Index

The overall median UA PI of the study cohort was 0.91 (0.79-1.04). Babies that required emergency delivery for fetal compromise (instrumental or caesarean) had the highest median UA PI (0.99, 0.80-1.14) while the two groups that had the lowest median UA PI were SVD (0.90, 0.79-1.02) and emergency delivery for failure to progress (0.90, 0.77-1.00).

The UA PI differed (p=0.01) between delivery groups. Infants born by emergency delivery for fetal compromise had higher UA PIs (0.99, 0.80-1.14) than those born by SVD (0.90, 0.79-1.02, p=0.002) and those born by emergency delivery for failure to progress (0.90, 0.77-1.00, p=0.004).

Sixteen point eight percent of babies (22/131) with a UA PI >90th centile (1.20) required emergency delivery for fetal compromise compared to only 8.4% (12/143) of infants with a UA PI <10th centile (0.69) and only 8.1% (90/1107) of infants with a UA PI 10th – 90th centile (p=0.004). The likelihood of having an emergency delivery for fetal compromise increased as the UA PI increased, OR 4.02 (95% CI 1.7-9.32), p=0.001. Conversely, a low UA PI was associated with a decreased risk, OR 0.25 (95% CI 0.11-0.58), p=0.001. Receiver-operator curve (ROC) analysis for the prediction of emergency delivery for fetal compromise using the UA PI found an area under the curve (AUC) of 0.58.

Middle Cerebral Artery Pulsatility Index

The median MCA PI for the entire cohort was 1.64 (1.41-1.89). The median MCA PI was lowest (1.54, 1.29-1.74) in babies who required emergency delivery (either caesarean section or instrumental delivery) for fetal compromise and highest (1.66, 1.45-1.91) in those

that were delivered by SVD. The MCA PI differed between delivery groups (p<0.001). The MCA PI was significantly lower in infants born by emergency delivery for fetal compromise (1.54, 1.29-1.74), compared to SVD (1.66, 1.45-1.91, p<0.001), elective caesarean section (1.65, 1.40-1.92, p<0.001) and emergency delivery for failure to progress (1.65, 1.40-1.96, p=0.004). The MCA PI was also lower in infants born by emergency caesarean section for other reasons (1.59, 1.43-1.79) compared to SVD (p=0.02).

Amongst infants with an MCA PI <10th centile (1.22), 14.4% (20/139) were delivered for fetal compromise (caesarean or instrumental), while only 8.5% (95/1119) with an MCA PI 10th-90th centile and 7.3% (9/123) with an MCA PI >90th centile required emergent delivery for fetal compromise, although this did not reach statistical significance (p=0.06). Fetuses with a lower MCA PI had an increased likelihood of having an emergency caesarean section for fetal compromise OR 2.90 (1.68-5.01), p<0.001, while those with a higher MCA PI had a reduced risk, OR 0.34 (0.20-0.60), p<0.001. Prediction of emergency delivery for fetal compromise using the MCA PI based on ROC analysis had an AUC of 0.61.

C/U ratio

The overall median C/U ratio for the entire cohort was 1.84 (1.49-2.23). Infants requiring emergency delivery for fetal compromise had the lowest C/U ratio of all the delivery groups with a median of 1.60 (1.22-2.08). The highest C/U ratio was found in infants that underwent emergency delivery for failure to progress (1.95, 1.54-2.30). The median C/U ratios differed between delivery groups (p<0.001).

The median C/U ratio was significantly lower in infants born by emergency delivery for fetal compromise (1.60, 1.22-2.08), compared to SVD (1.86, 1.56-2.21, p<0.001), elective caesarean section (1.6, 1.45-2.23, p=0.001) and emergency delivery for failure to progress (1.95, 1.54-2.30, p<0.001). The median C/U ratio was also lower in infants born by emergency caesarean section for other reasons 1.70 (1.40-2.24) compared to SVD (p=0.01) and compared to emergency delivery for failure to progress (p=0.03).

Table 2 details the maternal demographics, intrapartum and neonatal outcomes according to the C/U ratio stratified by percentile. The percentage of infants with a C/U ratio <10^{th} centile that required emergency delivery (caesarean section or instrumental) for fetal compromise was 22.0%, whereas only 7.3% of infants with a C/U ratio between 10^{th} - 90^{th} centile and 9.6% of infants with a C/U ratio >90^{th} centile required delivery for the same indication (p<0.001).

A lower C/U ratio was associated with an increased risk of emergency delivery for fetal compromise, OR 2.03 (95% CI 1.41-2.92), p<0.001. Conversely, a higher C/U ratio was associated with a reduced risk OR 0.49 (95% CI 0.34-0.71), p<0.001. Infants with a C/U ratio <10^{th} centile (<1.20) (141/1381) were three and a half times more likely to undergo emergency delivery for fetal compromise than those $\geq 10^{th}$ centile, OR 3.50 (95% CI 2.21-5.53), p<0.001. Conversely, a C/U ratio $\geq 10^{th}$ centile appeared to be protective against emergency delivery for fetal compromise, OR 0.21 (95% 0.13-0.35), p<0.001. Furthermore, babies with a C/U ratio <10^{th} centile were almost five times as likely to have an emergency delivery for fetal compromise than an SVD, OR 4.74 (95% CI 2.83-7.91), p<0.001. Prediction

of emergency delivery for fetal compromise based on the C/U ratio found an AUC of 0.61 using ROC analysis.

Forty-six point eight percent of infants required admission to the nursery if the C/U ratio was <10th centile compared to 18.9% in the 10th-90th centile group and 14.4% in the >90th centile group (p<0.001). Infants with a C/U ratio <10th centile had a greater proportion of primiparous patients, the lowest proportion of Caucasian ethnicity and the highest proportion of patients identified as indigenous (Table 2). These infants also had a lower proportion of deliveries by SVD, lower gestational age at delivery and lower birthweight (Table 2). There was no difference between C/U ratio centile groups for maternal age, maternal BMI and ethnicity categorized as Asian or Other. The was no difference in the proportion of infants delivered by elective caesarean or emergency delivery for failure to progress, Apgar scores < 7 at 5 minutes, cord arterial pH <7.2 or base excess <8 mmol/L (Table 2).

Discussion

The results of this large retrospective study suggests that a low fetal C/U ratio, measured late at term (median gestation of 36+1 weeks), is associated with an increased risk of intrapartum fetal compromise. This study demonstrates that a high UA PI, low MCA PI and low C/U ratio are all associated with an increased risk of emergency delivery for fetal compromise despite being measured some weeks remote from delivery. Furthermore, babies with a C/U ratio <10th centile were almost five times more likely to have an emergency delivery for fetal compromise than SVD. In other studies the C/U ratio has been found to be the single best predictor of poor perinatal outcome in growth restricted fetuses;

its sensitivity in detecting mild changes in placental resistance in combination with mild changes in cerebral vasodilatation appears to provide a more accurate assessment than each component alone [9] [10]. In other studies, term appropriately grown babies with low C/U ratios were at increased risk for intrapartum compromise [11] as well as poorer umbilical cord pH values at birth [12].

Our results are consistent with several previous studies. A prospective study of women assessed within 72 hours before delivery demonstrated that infants delivered by caesarean section for fetal compromise had significantly lower C/U ratios than those born by SVD (1.52 vs 1.83, $p<0.001$) [5]. Infants with a C/U ratio $<10^{th}$ percentile were 6 times more likely to be delivered by caesarean section for fetal compromise than those with a C/U ratio $\geq 10^{th}$ centile (OR, 6.1; 95% CI, 3.03-12.75). A C/U ratio $>90^{th}$ centile appeared to be protective of caesarean section for fetal compromise (negative predictive value 100%). Another large retrospective study of 11,576 fetuses demonstrated that appropriate for gestational age (AGA) fetuses on the lower birth weight centiles had significantly lower C/U values. The authors suggested a low C/U ratio might reflect the failure of a fetus to reach its growth potential, increased prevalence of fetal hypoxemia associated with lower neonatal birth weight and that these fetal Doppler indices may be better markers than fetal size alone for placental insufficiency and fetal hypoxemia [13]. The results from our study not only support these previous studies, but furthermore suggest that fetal Doppler indices, particularly the C/U ratio at 35-37 weeks may be useful for the prediction of intrapartum compromise despite the confounding effects of the process of parturition itself.

Despite the strengths of this study that include a large sample size obtained from a tertiary

centre representative of the general population, we acknowledge the limitations inherent in a retrospective study of this nature. Firstly, the study period spanned more than a decade, during which time evolution in hospital policies and guidelines from professional bodies may have influenced and changed practice. Secondly, the definition of fetal compromise was not standardized over the study period; it was based on the clinician's assessment of a diagnosis of "fetal distress" dependent on continuous fetal heart rate monitoring or fetal blood sampling. Although there are now clear guidelines from various professional bodies including the American College of Obstetricians & Gynaecologists [14], the Royal Australian and New Zealand College of Obstetricians and Gynaecologists [15] and the National Institute for Clinical Excellence in the United Kingdom [16] for interpretation of fetal heart rate patterns, such guidelines were not consistently available throughout the study period. Therefore indication for delivery was used as a surrogate instead. In most cases however, intrapartum fetal compromise would have been based on an abnormal fetal heart rate pattern although this could not be always confirmed. Thirdly, caregivers were not blinded to the antenatal ultrasound scan findings, which may have influenced intrapartum decision-making in some cases. Fourthly, it was difficult to correlate antenatal Doppler findings with markers of placental insufficiency such as placental histopathology and other neonatal outcomes given that this data was not available in most cases. Furthermore it was also difficult to be certain if there was consistency in the way the MCA Doppler waveform was obtained. Finally, our cohort was not an unselected population but rather women who were referred for an ultrasound assessment of fetal wellbeing because of various indications. Nevertheless, for the purposes of this study we only included women where there was no evidence of fetal growth restriction based on UA Dopplers, while accepting some of these babies could have had suboptimal growth despite normal UA resistance indices.

To our knowledge this is the first study that has investigated the relationship between the C/U ratio at 35-37 weeks and intrapartum fetal compromise in appropriately grown infants. Our group is currently conducting a prospective study to assess the utility of the C/U ratio earlier in pregnancy for the prediction of intrapartum fetal compromise. The results of this study, if validated in further prospective trials may influence how obstetricians stratify women according to their risk of subsequent intrapartum fetal compromise, and this perhaps may influence intrapartum management, help decide mode, timing or place of delivery. These studies would necessarily have to include large numbers of women given the paucity in high income countries of truly intrapartum related adverse neonatal outcomes.

References

[1] Janbu T and Nesheim BI. Uterine artery blood velocities during contractions in pregnancy and labour related to intrauterine pressure. Br J Obstet Gynaecol. 1987;94(12):1150-5.
[2] Bakker PC and van Geijn HP. Uterine activity: implications for the condition of the fetus. J Perinat Med. 2008;36(1):30-7.
[3] Low JA, Pickersgill H, Killen H and Derrick EJ. The prediction and prevention of intrapartum fetal asphyxia in term pregnancies. Am J Obstet Gynecol. 2001;184(4):724-30.
[4] Clark SL and Hankins GD. Temporal and demographic trends in cerebral palsy--fact and fiction. Am J Obstet Gynecol. 2003;188(3):628-33.
[5] Prior T, Mullins E, Bennett P and Kumar S. Prediction of intrapartum fetal compromise using the cerebroumbilical ratio: a prospective observational study. Am J Obstet Gynecol. 2013;208(2):124 e1-6.
[6] Prior T, Mullins E, Bennett P and Kumar S. Umbilical venous flow rate in term fetuses: can variations in flow predict intrapartum compromise? Am J Obstet Gynecol. 2014;210(1):61 e1-8.
[7] Hadlock FP, Harrist RB, Sharman RS, Deter RL and Park SK. Estimation of fetal weight with the use of head, body, and femur measurements--a prospective study. Am J Obstet Gynecol. 1985;151(3):333-7.
[8] Rothman KJ. No adjustments are needed for multiple comparisons. Epidemiology. 1990;1(1):43-6.
[9] Figueras F and Gratacos E. Update on the diagnosis and classification of fetal growth restriction and proposal of a stage-based management protocol. Fetal Diagn Ther. 2014;36(2):86-98.
[10] Bahado-Singh RO, Kovanci E, Jeffres A, Oz U, Deren O, Copel J and Mari G. The Doppler cerebroplacental ratio and perinatal outcome in intrauterine growth restriction. Am J Obstet Gynecol. 1999;180(3 Pt 1):750-6.
[11] Prior T, Paramasivam G, Bennett P and Kumar S. Are babies that fail to reach their genetic growth potential at increased risk of intra-partum fetal compromise? Ultrasound Obstet Gynecol. 2014 Dec 9. doi: 10.1002/uog.14758. [Epub ahead of print] PMID:25487285
.
[12] Morales-Rosello J, Khalil A, Morlando M, Bhide A, Papageorghiou A and Thilaganathan B. Poor neonatal acid-base status in term fetuses with low cerebroplacental ratios. Ultrasound Obstet Gynecol. 2014.
[13] Morales-Rosello J, Khalil A, Morlando M, Papageorghiou A, Bhide A and Thilaganathan B. Changes in fetal Doppler indices as a marker of failure to reach growth potential at term. Ultrasound Obstet Gynecol. 2014;43(3):303-10.
[14] ACOG. Practice Bulletin No. 106 - Intrapartum fetal heart rate monitoring: nomenclature, interpretation and general management principles. Obstet Gynecol. 2009;(114):192-202.
[15] RANZCOG. Intrapartum Fetal Surveillance. Clinical Guideline - Third Edition 2014. (https://www.ranzcog.edu.au/intrapartum-fetal-surveillance-clinical-guidelines.html). 2014.
[16] NICE. CG 55. Intrapartum care: Care of healthy women and their babies during childbirth. 2007.

Table 1: Patient demographics, mode of delivery and neonatal outcomes

Demographic	No. Obs	Overall	SVD	Emergency CS other	Elective CS	Emergency delivery for fetal compromise	Emergency delivery for failure to progress	Kruskall-Wallis/χ^2 *P* value
Number of patients	1381	1381	681	123	316	124	137	-
Primiparous	1381	577	37.2% (253/681)	41.5% (51/123)	27.2% (86/316)	68.5% (85/124)	74.5% (102/137)	< 0.001
Median maternal age	1381	30 (26-34)	29 (25-33)	31 (27-35)	32 (27-36)	29 (24-33.5)	30 (26-34)	< 0.001
Median BMI	1326	23 (20-27)	22 (20-26)	23 (21-28)	24 (21-29)	23 (21-27)	23 (20-30)	< 0.001
Ethnicity %	1381	-	-	-	-	-	-	-
Caucasian/ European	-	901	63.6% (433/681)	65% (80/123)	70.6% (223/316)	61.3% (76/124)	65.0% (89/137)	0.23
Asian	-	162	12.9% (88/681)	12.2% (15/123)	10.1% (32/316)	7.3% (9/124)	13.1% (18/137)	0.35
ATSI	-	50	3.1% (21/681)	7.3% (9/123)	4.7% (15/316)	3.2% (4/124)	0.7% (1/137)	0.04
Other	-	268	20.4% (139/681)	15.4% (19/123)	14.6% (46/316)	28.2% (35/124)	21.2% (29/137)	0.01
Median gestational age at delivery (weeks)	1381	38 (37-39)	38 (37-39)	37 (36-38)	37 (37-38)	38 36-39)	38 (37-39)	< 0.001
Birthweight (g)	1381	2870 (2478-3310)	2898 (2550-3310)	2730 (2270-3255)	2815 (2438-3326)	2565 (2198-3137)	3030 (2594-3420)	< 0.001
Apgar <7 at 5mins	1378	21	6	3	4	5	3	0.08
Cord artery pH < 7.2	46	12	9	1	0	2	0	0.17
Base excess > -8 mmol/L	25	3	3	0	0	0	0	0.54
NICU admission	541	295	13.8% (94/681)	35.0% (43/123)	26.6% (84/316)	43.5% (54/124)	14.6% (20/137)	< 0.001

Legend: SVD – Spontaneous Vaginal Delivery; CS – Caesarean Section; ATSI – Aboriginal and Torres Strait Islander; g – grams; NICU – Neonatal Intensive Care Unit

Table 2: CU ratios and outcomes

Demographic	Overall	CU Ratio < 10th percentile (1.20)	CU Ratio 10th – 90th percentile (1.21 – 2.63)	CU Ratio > 90th percentile (2.64)	Kruskall-Wallis/χ^2 *P* value
Number of patients	1381	141	1115	125	-
Primiparous	577	53.9% (76/141)	40.9% (456/1115)	36.0% (45/125)	0.005
Median maternal age	30 (26-34)	29 (25-33)	30 (26-34)	30 (26-34)	0.25
Median maternal BMI	23 (20-27)	23 (20-27)	23 (20-27)	24 (21-28)	0.25
Ethnicity	-	-	-	-	-
Caucasian	901	57.4% (81/141)	65.4% (729/1115)	72.8% (91/125)	0.03
Asian	162	12.1% (17/141)	11.9% (133/1115)	9.6% (12/125)	0.74
ATSI	50	9.2% (13/141)	3.3% (37/1115)	0.0% (0/125)	< 0.001
Other	268	21.3% (30/141)	19.4% (216/1115)	17.6% (22/125)	0.75
SVD	681	32.6% (46/141)	51.7% (577/1115)	46.4% (58/125)	< 0.001
Emergency CS other	123	14.2% (20/141)	7.9% (88/1115)	12.0% (15/125)	0.02
Elective CS	316	24.1% (34/141)	23.1% (258/1115)	19.2% (24/125)	0.57
Emergency delivery for fetal compromise	124	22.0% (31/141)	7.3% (81/1115)	9.6% (12/125)	< 0.001
Emergency delivery for failure to progress	137	7.1% (10/141)	10.0% (111/1115)	12.8% (16/125)	0.30
Median gestational age at delivery	38 (37-39)	36 (36-37)	38 (37-39)	39 (37-40)	< 0.001
Birthweight (g)	2870 (2478-3310)	2212 (1969-2564)	2820 (2528-3300)	3327 (2888-3755)	< 0.001
Apgar <7 at 5mins	21	3	14	4	0.20
Cord artery pH < 7.2	12	2	10	0	0.45
Base excess > -8mmol/L	3	0	3	0	0.70
NICU admission	295	46.8% (66/141)	18.9% (211/1115)	14.4% (18/125)	< 0.001

Legend: SVD – Spontaneous Vaginal Delivery; CS – Caesarean Section; ATSI – Aboriginal and Torres Strait Islander; g – grams; NICU – Neonatal Intensive Care Unit; CU – Cerebro-umbilical

Highlights

- We assessed the relationship of the fetal C/U ratio at 35-37 weeks with intrapartum outcomes
- Babies with fetal compromise had lower C/U ratios compared to all other delivery groups
- A high ratio appears to be protective against intrapartum compromise
- Prenatal measurement of the C/U ratio may be useful in risk stratification prior to labour