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TITLE:

Variation in hospital caesarean rates among nulliparae at term is unexplained and unrelated to maternal or neonatal outcome: a population based cohort study.

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ABSTRACT

OBJECTIVE

To explore variation in hospital caesarean rates for nulliparous women; determine whether casemix, labour and delivery, and hospital factors explain the variation and examine the association between hospital caesarean rates and outcomes.

DESIGN

Population-based cohort study.

SETTING

New South Wales, 2009-2010.

POPULATION

Nulliparous women with singleton cephalic live births at term.

METHODS

Random effects multilevel logistic regression models using linked hospital discharge and birth data.

MAIN OUTCOME MEASURES

Prelabour, and intrapartum caesarean rates following spontaneous labour or labour induction; maternal and neonatal severe morbidity rates.

RESULTS

Of 67,239 nulliparous women, 4,902 (7.3%) had prelabour caesareans, 39,049 (58.1%) had spontaneous labour and 23,288 (34.6%) had induction of labour. Overall, there were 18,875 (28.1%) caesareans, with labour inductions twice as likely to end in an intrapartum caesarean than spontaneous labour (34.0% versus 15.5%).

After adjusting for casemix, labour and delivery, and hospital factors, the overall variation in caesarean rates decreased by 78% for prelabour caesareans; for intrapartum caesarean by 52% following spontaneous labour and by 9% following labour induction. However, adjusting for labour and delivery practices increased the unexplained variation in intrapartum caesareans.

The rates of severe maternal and neonatal morbidity were not significantly different across caesarean rate quintile groups, except for women in spontaneous labour, where the hospitals in the lowest caesarean quintile had the lowest neonatal morbidity rate.

CONCLUSIONS

Differences in clinical practice were substantial contributors to variations in intrapartum caesarean rates. Strategies aiming at lowering the caesarean rate should not adversely affect maternal or neonatal outcome.

KEYWORDS

Caesarean section; term nullipara; maternal outcome; neonatal outcome; labour, induction; spontaneous labour;

INTRODUCTION

Caesarean rates have increased in high and middle income countries over the last decade; rates in the United States (US) and the United Kingdom (UK) have risen by over 50%, peaking at 24.9% and 31.3% respectively.[1,2] Likewise, the caesarean rate in Australia has increased from 23.3% in 2000 to 31.6% in 2010.[3] It is pertinent that international and national caesarean rates have not been accompanied with population level improvement in maternal and neonatal outcomes.[4]

Internationally, nulliparous women with singleton term cephalic births constitute 35-43% of the overall caesarean rate.[5] Caesarean rates among these women are deemed potentially modifiable and as such this group is one of the core maternity quality indicators in the USA.[6] A number of studies have demonstrated there is substantial unexplained variation in hospital caesarean rates for nulliparous women, despite adjusting for casemix[7-9] and hospital factors.[9] However, other clinical factors such as onset of labour may also contribute to variation in rates.[10] Therefore the aims of this study were to: explore variation in hospital caesarean section rates for nulliparous women with singleton term cephalic births by onset of labour; determine to what extent this can be explained by casemix, labour and delivery, and hospital factors; and examine the association between hospital caesarean rates and maternal and neonatal outcomes.

METHODS

The study population included nulliparous women with singleton cephalic live births at term (≥37 weeks gestation) in New South Wales (NSW) hospitals between 2009 and 2010. NSW is Australia's most populous state with 7 million residents and 95,000 births per annum (32% of all Australian births).[11]

Data source and study variables

Data were obtained from two linked NSW population databases: the Perinatal Data Collection (PDC) and the Admitted Patient Data Collection (APDC). The PDC is a legislated population-based surveillance system covering all live births, and stillbirths of at least 20 weeks gestation or at least 400 grams birthweight. Information includes maternal demographic, medical and obstetric information and infant outcomes. The APDC is a census of hospital discharges from all NSW hospitals, which includes patient characteristics, diagnoses and procedures coded according to the 10th revision of the International Classification of Disease, Australian Modification and the Australian Classification of Health Interventions. Probabilistic record linkage was undertaken by the NSW Centre for Health Record Linkage (CHeReL). For this study, quality assurance data show false positive and negative rates of 0.3% and <0.5% respectively. The researchers were provided with anonymised records, with ethical approval for the study from the NSW Population and Health Services Research Ethics Committee.

The primary outcome was the caesarean rate for each hospital. Public and private hospitals with continuous obstetric services during the study period and with ≥50 births per annum were included. Births were categorised according to 3 risk-based, mutually exclusive groups for nulliparous women using the Robson classification:[12] prelabour caesarean rates among women with births ≥37 weeks gestation, intrapartum caesarean rates among women with spontaneous labour at ≥37 weeks gestation and intrapartum caesarean rates among women with labour induction at ≥37 weeks gestation. Onset of labour is reliably collected in the birth record.[13]

Potential risk factors for caesarean were categorised into three groups: casemix factors, labour and delivery factors, and hospital factors. *Casemix* factors obtained from birth records included maternal age, country of birth, socio-economic status [14], geographic remoteness of

residence,[15] smoking in pregnancy, private obstetric care, first antenatal care visit before 20 weeks' gestation, and factors derived from birth records linked to maternal hospital records within the 5 years prior to or at birth including diabetes (pre-existing or gestational), hypertension (chronic or gestational hypertension, preeclampsia or eclampsia), placental conditions (placenta praevia, placenta abruption, antepartum haemorrhage), previous miscarriage, and chronic diseases (cardiac diseases, chronic kidney disease, autoimmune diseases and inflammatory bowel disease). *Labour and delivery* factors obtained from birth records were gestational age, use of oxytocin and/or prostaglandin, and regional labour analgesia. *Hospital factors* obtained from birth records were birth volume, location of hospital (urban or rural), hospital type (public or private), proportion of caesareans performed under general anaesthetic and proportion of births where regional analgesia is used (as indicators of anaesthetic service), induction/augmentation rate, instrumental birth rate and obstetric training (primary referring to tertiary obstetric training hospitals, secondary referring to large district and rural hospitals that host obstetric registrars, and non-training hospitals). The analysis used reliably reported variables.[13]

Statistical analyses

Multilevel logistic regression with a random intercept for each hospital was used to examine variation in caesarean rates among hospitals adjusting for differences in individual-level and hospital-level factors while taking into account similarities of births within hospitals. Such models incorporate a 'shrinkage' factor, where less precise rates (from smaller hospitals) are down-weighted towards the overall average. Following the method described by Lee et al,[16] multilevel models were fitted in a stepwise manner within each Robson group. The first (unadjusted) model, including only hospital intercepts, and thereafter models were sequentially adjusted for casemix, labour and delivery, and hospital factors. (See Appendix for detailed information about the multilevel logistic regression modelling.)

To illustrate the differences in hospital caesarean rates after each step of adjustment, we calculated and plotted the risk-adjusted hospital caesarean rates with 95% confidence intervals (95% CI). The relative contribution of each step of adjustment to the overall reduction in variation in hospital caesarean rates was quantified by calculating the difference between the variation of the current and preceding models, as a proportion of the unadjusted model's variation.

Finally, we examined the association between hospital caesarean rates and hospital maternal and neonatal morbidity rates. As the patterns and associations of maternal and neonatal morbidity outcomes (postpartum haemorrhage, severe maternal morbidity, Apgar scores at one and five minutes, neonatal resuscitation, admission to neonatal intensive care and severe neonatal morbidity) with hospital caesarean rates were similar, only severe maternal and neonatal morbidity are reported. Severe morbidity was measured using validated composite outcome indicators that were developed specifically for use in administrative hospital data.[17,18] Maternal and neonatal morbidity rates were adjusted for maternal casemix, whereas the caesarean rates were additionally adjusted for labour, delivery, and hospital factors (as above). We plotted the hospital caesarean rates against the hospital maternal and neonatal morbidity rates to examine patterns of association. To quantify any relationships, hospitals were ranked according to their risk-adjusted caesarean rates and divided into quintiles. Casemix adjusted maternal and neonatal morbidity rates within each caesarean quintile were then averaged and the adjusted odds ratios with confidence intervals were compared. Statistical analyses were performed using SAS (version 9.3; SAS Institute, Cary, North Carolina).

RESULTS

Individual characteristics of the study population

In 2009 and 2010 there were 70,272 nulliparous singleton, cephalic births of ≥37 weeks gestation in NSW including 67,239 (95.7%) in the 81 hospitals having ≥50 births per annum.

Of these, 4,902 (7.3%) were prelabour caesareans, 39,049 (58.1%) had spontaneous labour and 23,288 (34.6%) followed induction of labour. Overall, there were 18,875 (28.1%) caesarean sections, including 4,902 prelabour caesareans, 6,049 intrapartum caesareans among women who had spontaneous labour and 7,924 intrapartum caesareans among women who had labour induced. Overall, 1,824 (2.7%) women and 1,670 (2.4%) infants were classified as suffering severe morbidity. Casemix and labour and delivery factors by onset of labour and mode of delivery are presented in Table 1.

Characteristics of the 81 NSW hospitals

Of the 81 hospitals, 15 (18.5%) were private, 48 (59.3%) were rural and/or 29 (35.8%) provided either primary or secondary obstetric training. Over the study period, the median hospital volume of nulliparous singleton, cephalic births at term was 532 births, median caesarean with general anaesthetic rate was 11.9%, median regional analgesia rate was 27.4%, median induction/augmentation rate was 46.3% and median instrumental birth rate was 20.6%.

Variation in hospital prelabour caesarean rates

Among all nulliparous women who delivered a singleton cephalic infant at term, the unadjusted hospital prelabour caesarean rates ranged from 2.6% to 20.2% (Figure 1A). After adjusting for casemix, the unexplained variation between hospitals reduced by 62.8% with adjusted caesarean rates (aCR) ranging from 3.3% to 22.8% (Table 2, Figure 1B). Adjustment for labour factors was not relevant for the analysis of prelabour caesarean section. However, adjustment for hospital factors further reduced the unexplained variation by 15.1% (Table 2, aCR from 4.1% to 17.8%, Figure 1C). Hospital type was the only significant hospital-level predictor of prelabour caesarean; nulliparous women in a private hospital had significantly higher odds of prelabour caesarean than those in a public hospital (aOR 2.03, 95% CI 1.40, 2.95) (Table S1). Overall, the final model explained 77.9% of the variation in hospital prelabour caesarean rates, mostly due to casemix.

Variation in hospital intrapartum caesarean

Among women in *spontaneous labour*, the unadjusted hospital intrapartum caesarean rates ranged from 7.6% to 24.9% (Figure 2A). After adjusting for casemix, the unexplained variation between hospitals reduced by 19.7% (Table 2, aCR 7.6% to 22.8%, Figure 2B). Additionally adjusting for labour and delivery factors increased unexplained variation by 10.1% compared to the previous model (Table 2, aCR 8.0% to 28.6%, Figure 2C). Finally, additionally adjusting for hospital factors markedly reduced the unexplained variation by 42.0% (Table 2, aCR 10.4% to 23.4%, Figure 2D). Women with spontaneous labour delivering at public hospitals without primary or secondary obstetric training had a significantly higher odds of intrapartum caesarean, aOR 2.10, 95% CI [1.27, 3.49] for urban hospitals and aOR 1.53, 95% CI [1.16, 2.02] for rural hospitals, compared to those delivering at urban public hospitals with primary obstetric training (Table S2). Overall, 51.6% of the variation in hospital intrapartum caesarean rates for women who had a spontaneous labour was explained, mostly due to hospital factors.

Among women with *labour induction*, the unadjusted hospital intrapartum caesarean rates ranged from 20.0% to 42.8% (Figure 3A). After adjusting for casemix, the unexplained variation between hospitals increased by 30.0% (Table 2, aCR 19.2% to 46.2%, Figure 3B). Adjusting for labour and delivery factors further increased the unexplained variation by 43.9% (Table 2, aCR 16.4% to 47.7%, Figure 3C). Finally, additionally adjusting for hospital type reduced unexplained variation by 8.7% compared to the previous models (Table 2, aCR 22.2% to 44.8%, Figure 3D). Compared with primary training hospitals, the risk of intrapartum caesarean following labour induction was significantly lower at private hospitals (aOR 0.69, [95% CI 0.53, 0.90]) and there was a tendency (non-significant) to increased risk in non-training and rural hospitals (Table S3). The final model suggests that overall, 8.7% of

the variation in hospital intrapartum caesarean rates for women who had a labour induction was explained, all due to hospital factors.

Association between caesarean rates and obstetric outcomes

Casemix adjusted hospital rates of severe maternal and neonatal morbidity ranged from 1.8% to 4.4% and 1.0% to 6.7% respectively. There was no clear relationship between overall risk-adjusted hospital caesarean rates by Robson groups and casemix adjusted severe maternal or neonatal morbidity rates (Figures 4–6). For all three groups, the rates of severe maternal and neonatal morbidity were not significantly different across the quintiles of hospital caesarean rates (Table 3), except for women with spontaneous labour, where the hospitals in the lowest caesarean quintile had the lowest casemix adjusted neonatal morbidity rate (1.6%).

DISCUSSION

MAIN FINDINGS

In NSW between 2009 and 2010, 28.1% of nulliparous women with a singleton cephalic infant at term had a caesarean, which accounted for 35%[7] of the total caesareans. Consistent with findings from the US and UK, we found unexplained variation in hospital caesarean rates among nulliparous women at term even after adjusting for casemix (7-9), but variation persisted after stratifying by labour onset and adjusting for labour and delivery and hospital factors. To our knowledge this is the first study to explore variation in caesareans rates among nulliparous women at term stratified by labour onset. Persistent variation suggests differences in clinical practices among hospitals may potentially increase health care costs without improving obstetric outcomes.[16]

STRENGTHS AND LIMITATIONS

The strengths of this study were the use of large, contemporary, population-based data and the availability of reliably collected labour, birth and outcome information. Like most high and

middle income countries, there are a wide range of maternity care options in Australia (public and private, doctor and midwife-led), and the findings may be generalisable to other settings with a range of practices. Furthermore, the method used could be applied in regional, national and international settings. A shrinkage factor was used to reduce the impact of random fluctuations in low volume hospitals and multilevel modelling for risk adjustment allowed quantification of the contribution of casemix, labour and delivery factors, and hospital factors to the variation in hospital caesarean rates, while accounting for similarities of births within hospitals. Additionally, we were able to report on maternal and neonatal outcomes in the hospitals by caesarean section rate quintiles. However, administrative data does not allow exploration of clinical variation in thresholds; reasons for and methods of labour induction; physician and patient attitudes; or cultural influences on decision-making and therefore these warrant further investigation.

INTERPRETATION

Variation in hospital prelabour caesarean rates

The prelabour caesarean rate (35%) was consistent with reported rates for high income countries.[5,19] We found much (77.9%) of the variation in prelabour caesarean rates was explained by casemix, which suggests that differences in prelabour caesarean rates reflect the heterogeneous population in the hospital rather than differing clinical management of these women. Nevertheless, after adjusting for casemix, a nulliparous woman with a singleton cephalic infant at term was twice as likely to have a prelabour caesarean in a private hospital compared to a tertiary public hospital. Similarly, an increased risk of prelabour caesarean have been reported among Irish nulliparous women delivering in private hospitals compared to public hospitals.[20] It is unclear whether these patterns reflect women's or clinician's preferences for management.

Variation in hospital intrapartum caesarean rates after spontaneous labour

In contrast to prelabour caesarean rates, casemix only explained 19.7% of hospital variance in intrapartum caesarean rates after spontaneous labour. Differences in clinical practice were a substantial contributor to the variation in hospital intrapartum caesarean rates, with labour and delivery factors increasing hospital variation by 12.6%. There may be an opportunity to reduce variation by developing guidelines for standardised labour management. For example, one UK study found that hospitals with written guidelines for the management of labour had a lower caesarean rate compared to those without written guidelines.[21] Like other studies, we found a higher caesarean rate at hospitals without primary or secondary obstetric training. Obstetric trainees in a hospital may encourage updated work practices, and the presence of obstetric training may be a modifiable hospital factor.[9]

Variation in hospital intrapartum caesarean rates after induction of labour

The persisting variation in caesarean rates following labour induction was especially concerning given the prevalence (35%) of this procedure and the emerging perception that induction of labour reduces the likelihood of caesarean birth.[22] Despite adjusting for casemix, variation in hospital intrapartum caesarean rates after induction of labour increased, suggesting that the same pregnant woman with an induction of labour at different hospitals would have a different risk of caesarean. Therefore, practice changes based on beliefs that induction reduces caesarean births will carry significant implications for those settings where the risk of caesarean is high. After additionally controlling for labour and delivery factors, variation in hospital intrapartum caesarean rates increased further, which indicate that it is not induction itself, but the decision making and processes of the induction that lead to caesarean birth. For example, women may be induced for varying indications or there may be different thresholds for offering induction of labour. A comparison of guidelines for induction of labour indicates agreement on only 14% (3 out of 21) of the various indications for induction of labour among the American College of Obstetricians and Gynaecologists, Society of Obstetricians and Gynaecologists of Canada and the Royal

College of Obstetricians and Gynaecologists.[23] Additionally, there are variations in the methods used to initiate labour between hospitals[24] and within countries.[25] Finally, differences in hospital factors were found to account for some of the variation in hospital intrapartum caesarean rates following induction of labour, and the low rates among private hospitals may reflect a greater likelihood of prelabour caesarean in these settings, inadequate adjustment for case-mix or use of different methods of induction. Variations in the decision making and the clinical practice of induction may be amenable to change through quality improvement processes.

The appropriateness of any caesarean section rate can only be interpreted if the attendant morbidity and mortality is known. Previous studies have found conflicting associations between casemix adjusted hospital caesarean rates and maternal and neonatal outcomes,[26-28] with some studies finding neonatal morbidity increased with both high and low casemix adjusted caesarean rates [26,27] and another finding no association between neonatal morbidity and casemix adjusted caesarean rates.[28] This may be due to the reporting of different neonatal outcomes (5 minute Apgar score <7[28] or neonatal asphyxia[26]) for the overall casemix adjusted hospital caesarean rate. In contrast, we reported maternal and neonatal outcomes by onset of labour and used validated composite maternal and neonatal outcome indicators. Reassuringly, we found that lower rates of caesarean section were not associated with worse maternal or neonatal outcomes. Additionally, the lowest neonatal morbidity rates were among women who had an intrapartum caesarean following spontaneous labour and delivered in the hospitals with the lowest caesarean rate quintile. Our findings suggest strategies and interventions aimed at lowering the caesarean rate would not adversely affect maternal or neonatal outcome.

Casemix, labour and delivery, and hospital factors have differing levels of importance in explaining variation in hospital caesarean rates for nulliparous women with singleton term cephalic births in the 3 mutually exclusive labour onset categories. This suggests

heterogeneity in the intrapartum management of labour, whether spontaneous or a result of an induction process, with the least amount of heterogeneity in management of women having pre-labour caesareans. Separating the effects of these factors highlight some of the potentially modifiable factors that could be targeted for more standardised clinical management. This study potentially identifies hospitals for clinical audit, such as those hospitals with lower caesarean rates but with unchanged or improved maternal and neonatal outcomes, that could provide additional insights into how to improve maternity care.

CONCLUSION

Casemix, labour and delivery and hospital factors explained a large proportion (78%) of the variation between hospitals in the rates of prelabour caesarean section for nulliparous women at term, but these factors only explained 52% and 9% of the variation in rates of intrapartum caesareans following spontaneous labour and labour induction respectively. For intrapartum caesarean rates, labour and delivery factors increased the variation between hospitals. As there were no significant differences in rates of severe maternal or neonatal morbidity across adjusted hospital caesarean rate quintile groups, intrapartum strategies to reduce hospital caesarean section rates should not adversely affect maternal or neonatal outcome.

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DISCLOSURE OF INTERESTS

The authors have no conflicts of interest to report.

CONTRIBUTION TO AUTHORSHIP

CR, MN and JM conceived the study and CR co-ordinated the project. All authors participated in the study design, planning of analysis and interpretation of the results. YYL undertook the data preparation and statistical analyses with JP providing statistical expertise. CR, TN, JF and YYL drafted the manuscript. MN, TN and JM provided expertise on clinical and health service interpretations. All authors critically reviewed drafts of the manuscript, read and approved the final manuscript.

DETAILS OF ETHICS APPROVAL

Ethical approval for the study was obtained from the NSW Population and Health Services Research Ethics Committee on 12th July, 2013 (Reference number: HREC/12/CIPHS/85).

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TABLE CAPTION LIST

FIGURE CAPTION LIST

SUPPORTING INFORMATION

Table S1: Among all nulliparous women at term, adjusted odds ratios and 95% confidence intervals for hospital prelabour caesarean sections

Table S2: Among nulliparous women with spontaneous labour, adjusted odds ratios and 95% confidence intervals for hospital intrapartum caesarean sections

Table S3: Among nulliparous women with labour induction, adjusted odds ratios and 95% confidence intervals for hospital intrapartum caesarean sections

Table 1: Casemix, labour and delivery characteristics of the study population, New South Wales, 2009–2010

Individual factor	Nulliparous women with singleton cephalic-presenting infants ≥37 weeks gestation					
	Spontaneous labour		Labour induction		All nulliparous women	
	CS	No CS	CS	No CS	Prelabour CS	No prelabour CS
	(*N* = 6,049)	(N = 33,000)	(N = 7,924)	(N = 15,364)	(*N* = 4,902)	(*N* = 62,337)
Maternal age[a]	30.1 (5.51)	28.0 (5.50)	30.1 (5.58)	28.6 (5.57)	32.6 (5.52)	28.6 (5.59)
Country of birth						
Australia or New Zealand	4,001 (66.1)	21,921 (66.4)	5,385 (68.0)	11,162 (69.8)	3,211 (65.5)	42,116 (67.6)
Asia	1,208 (20.0)	6,310 (19.1)	1,544 (19.5)	2,540 (16.5)	926 (18.9)	11,602 (18.6)
Others	840 (13.9)	4,769 (14.5)	995 (12.6)	2,015 (13.1)	765 (15.6)	8,619 (13.8)
Index of Education and Occupation						
1st quintile (high education/occupation)	1,717 (28.4)	7,386 (22.4)	1,816 (22.9)	3,293 (21.4)	1,775 (36.2)	14,212 (22.8)
2nd quintile	1,244 (20.6)	6,755 (20.5)	1,754 (22.1)	3,343 (21.8)	1,118 (22.8)	13,096 (21.0)
3rd quintile	1,198 (19.8)	6,781 (20.6)	1,686 (21.3)	3,221 (21.0)	826 (16.9)	12,886 (20.7)
4th quintile	871 (14.4)	6,273 (19.0)	1,307 (16.5)	2,904 (18.9)	607 (12.4)	11,355 (18.2)
5th quintile (low education/occupation)	1,019 (16.9)	5,805 (17.6)	1,361 (17.2)	2,603 (16.9)	576 (11.8)	10,788 (17.3)
ARIA+ remoteness						

Major cities	4,330 (71.6)	23,431 (71.0)	5,644 (71.2)	10,933 (71.2)	3,764 (76.8)	44,338 (71.1)
Rural	1,680 (27.8)	9,343 (28.3)	2,235 (28.2)	4,316 (28.1)	1,119 (22.8)	17,574 (28.2)
Remote	39 (0.6)	226 (0.7)	45 (0.6)	115 (0.8)	19 (0.4)	425 (0.7)
Smoking in pregnancy	498 (8.2)	3,803 (11.5)	657 (8.3)	1,479 (9.6)	335 (6.8)	6,437 (10.3)
Private obstetric care	2,712 (44.8)	11,155 (33.8)	3,224 (40.7)	6,135 (39.9)	3,731 (76.1)	23,226 (37.3)
Diabetes	814 (10.3)	1,300 (8.5)	236 (3.9)	1,125 (3.4)	368 (7.51)	3,475 (5.57)
Hypertension	1,791 (22.6)	3,018 (19.6)	598 (9.9)	2,080 (6.3)	829 (16.91)	7,487 (12.01)
Other chronic medical conditions	175 (2.2)	296 (1.9)	104 (1.7)	186 (1.5)	178 (3.63)	1,061 (1.70)
Placental conditions	282 (3.6)	452 (2.9)	245 (4.1)	758 (2.3)	643 (13.1)	1,737 (2.8)
Antenatal care <20 weeks	5,720 (94.6)	30,530 (92.5)	7,507 (94.7)	14,350 (93.4)	4,648 (94.8)	58,107 (93.2)
Assisted reproductive technology	236 (3.9)	934 (2.8)	337 (4.3)	565 (3.7)	579 (11.8)	2,072 (3.3)
Birthweight percentiles (grams)						
<10th	594 (9.8)	4,154 (12.6)	913 (11.5)	2,084 (13.6)	514 (10.5)	7,745 (12.4)
>90th	665 (11.0)	1,573 (4.8)	980 (12.4)	968 (6.3)	669 (13.7)	4,186 (6.7)
Prior miscarriage	383 (6.3)	1,577 (4.8)	552 (7.0)	915 (6.0)	521 (10.6)	3,427 (5.5)
Estimated gestational age (weeks)[a]	39.6 (1.08)	39.4 (1.07)	39.9 (1.24)	39.7 (1.27)	38.8 (1.09)	39.5 (1.16)
Regional labour analgesia	3,888 (64.3)	9,980 (30.2)	5,214 (65.8)	7,951 (51.8)	–	–

Augmentation with oxytocin	2,884 (47.7)	8,809 (26.7)	–	–	–	–
Induction with oxytocin	–	–	5,993 (75.6)	11,541 (75.1)	–	–
Induction with prostaglandin	–	–	4,592 (58.0)	7,645 (49.8)	–	–
Severe maternal morbidity	156 (2.58)	797 (2.42)	229 (2.89)	523 (3.40)	119 (2.43)	1,705 (2.74)
Severe neonatal morbidity	251 (4.15)	570 (1.73)	308 (3.89)	375 (2.44)	166 (3.39)	1,504 (2.41)

[a] Mean (standard deviation)

Table 2: Percent contribution to the overall reduction in variation in hospital caesarean section rates (relative to the unadjusted model's variation)

Percent contribution	Casemix factors	Labour and delivery factors	Hospital factors	Overall
Pre-labour caesarean	-62.8	–[a]	-15.1	-77.9
Intrapartum caesarean				
Spontaneous labour	-19.7	10.1[b]	-42.0	-51.6
Labour induction	30.0	43.9[b]	-82.6	-8.7

[a] Adjustment for labour and delivery factors was not relevant for the analysis of prelabour caesarean section

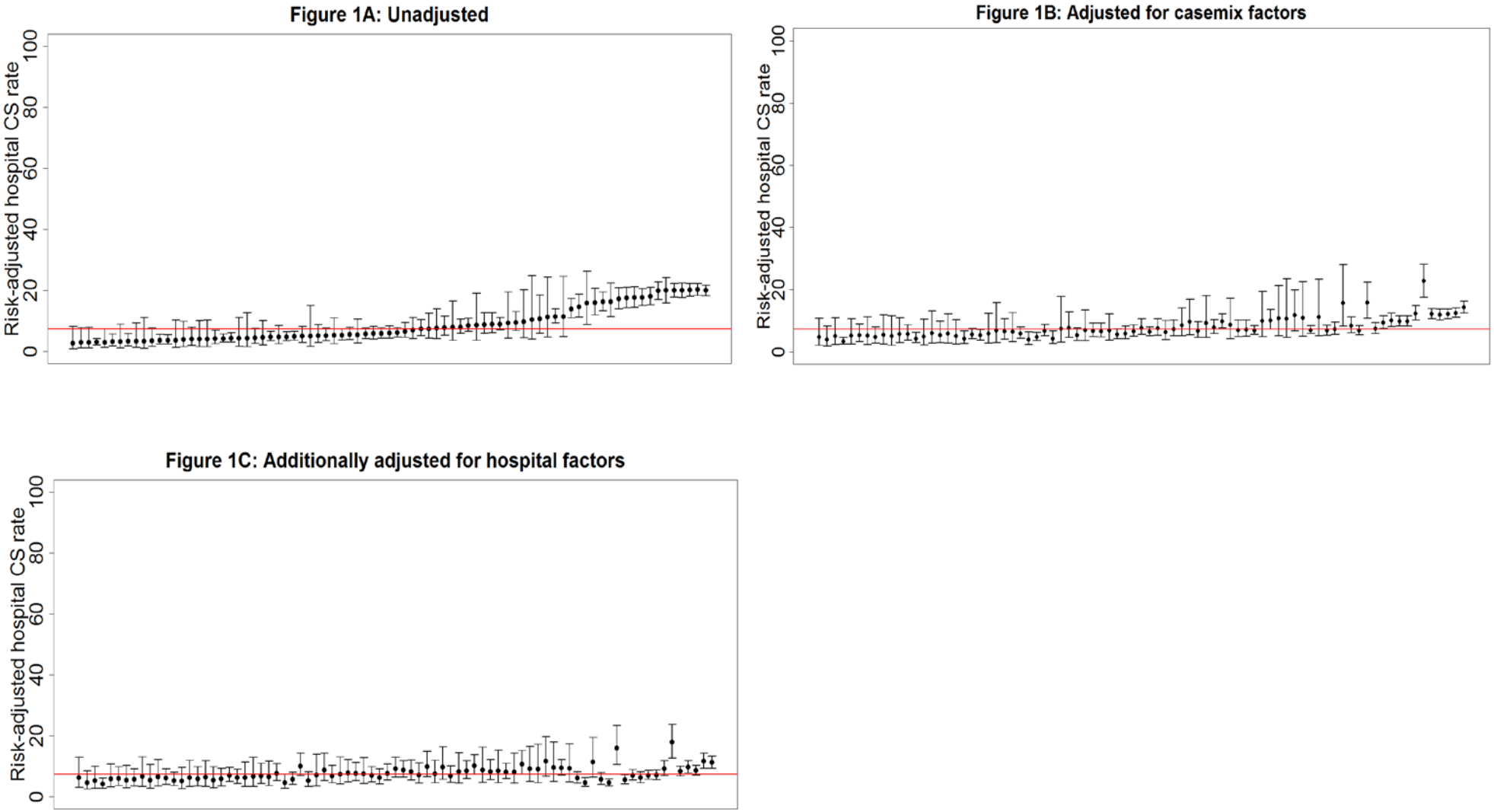
[b] For intrapartum caesareans, adjustment for labour and delivery factors, did not reduce, but rather increased the unexplained variation between hospitals.

Table 3: Case-mix adjusted severe maternal and neonatal morbidity rates, odds ratios and 95% confidence intervals across the hospital caesarean rate quintiles

Hospital caesarean quintile	Maternal			Neonatal		
	Rate [95% CI]	OR [95% CI]	*P* val	Rate [95% CI]	OR [95% CI]	*P* val
Prelabour caesarean						
1st quintile (lowest)	3.0 [2.7,3.3]	1.06 [0.83,1.37]	0.64	2.6 [2.3,2.9]	1.01 [0.68,1.49]	0.98
2nd quintile	2.8 [2.4,3.2]	1.05 [0.80,1.37]	0.75	2.5 [2.1,2.9]	0.84 [0.56,1.28]	0.42
3rd quintile	2.7 [2.4,2.9]	1.09 [0.85,1.39]	0.50	2.4 [2.1,2.6]	0.97 [0.66,1.43]	0.87
4th quintile	2.7 [2.5,2.9]	1.11 [0.87,1.42]	0.38	2.4 [2.1,2.6]	0.79 [0.53,1.17]	0.24
5th quintile (highest)	2.5 [2.2,2.7]	Reference		2.6 [2.4,2.9]	Reference	
ALL	2.7 [2.6,2.8]		–	2.5 [2.4,2.6]		–
Caesarean after spontaneous labour						
1st quintile (lowest)	2.5 [2.1,2.8]	1.00 [0.76,1.31]	1.00	1.6 [1.4,1.9]	0.62 [0.43,0.88]	0.01
2nd quintile	2.1 [1.8,2.5]	0.92 [0.68,1.23]	0.56	2.0 [1.7,2.4]	0.78 [0.54,1.13]	0.19
3rd quintile	2.5 [2.2,2.9]	1.15 [0.87,1.51]	0.33	2.5 [2.2,2.8]	0.95 [0.67,1.36]	0.79
4th quintile	2.4 [2.0,2.8]	0.99 [0.74,1.32]	0.94	2.1 [1.7,2.4]	0.83 [0.58,1.19]	0.32
5th quintile (highest)	2.5 [2.2,2.9]		Reference	2.2 [1.9,2.5]		Reference
ALL	2.4 [2.3,2.6]		–	2.1 [1.9, 2.2]		–
Caesarean after labour induction						

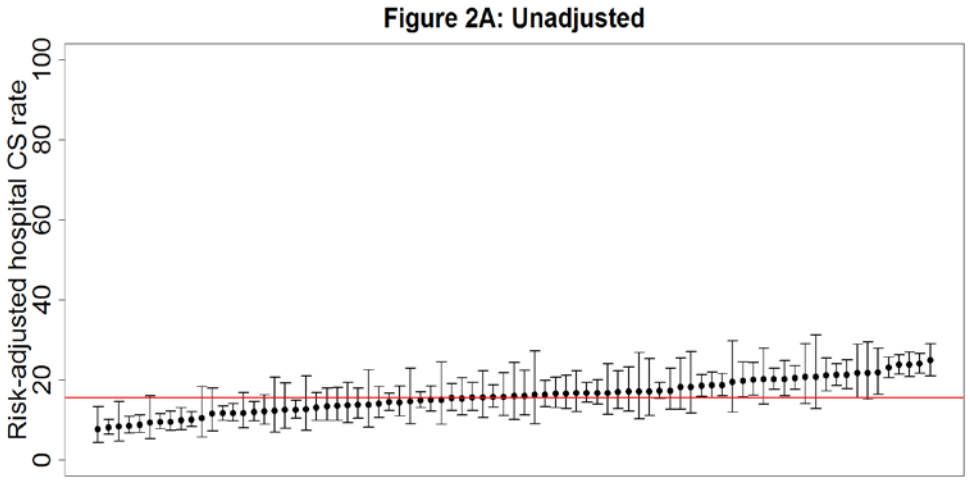
1st quintile (lowest)	3.1 [2.6,3.6]	1.17 [0.90,1.51]	0.23	3.0 [2.5,3.5]	1.16 [0.72,1.88]	0.54
2nd quintile	3.3 [2.8,3.8]	1.03 [0.80,1.34]	0.80	2.8 [2.3,3.2]	1.08 [0.66,1.78]	0.76
3rd quintile	3.4 [2.7,4.1]	1.14 [0.84,1.55]	0.39	3.3 [2.7,4.0]	1.13 [0.65,1.98]	0.66
4th quintile	3.2 [2.8,3.7]	1.10 [0.86,1.40]	0.46	2.7 [2.2,3.1]	1.09 [0.69,1.74]	0.71
5th quintile (highest)	3.1 [2.6,3.5]		Reference	2.9 [2.5,3.4]		Reference
ALL	3.0 [3.0,3.4]		–	2.9 [2.7,3.1]		–

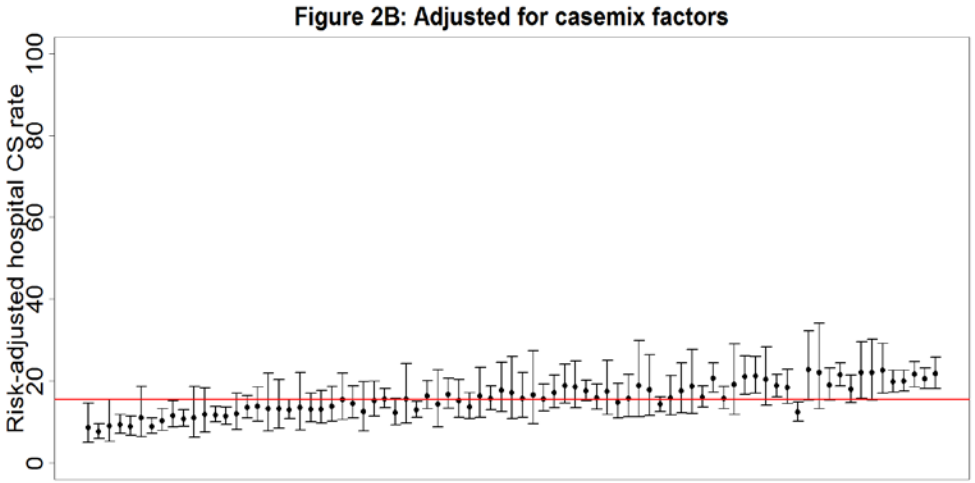
Figure 1: Hospital prelabour caesarean rates among nulliparous women with a singleton, cephalic-presenting infant of ≥37 weeks gestation

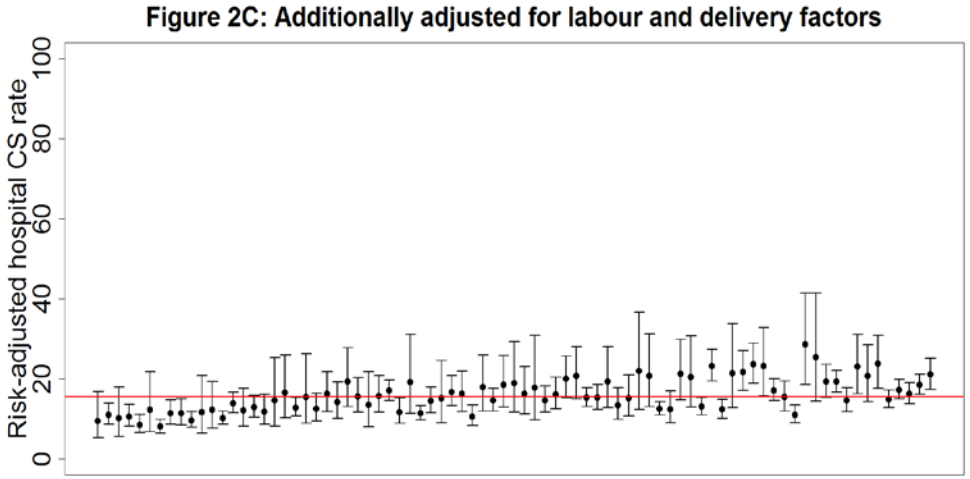


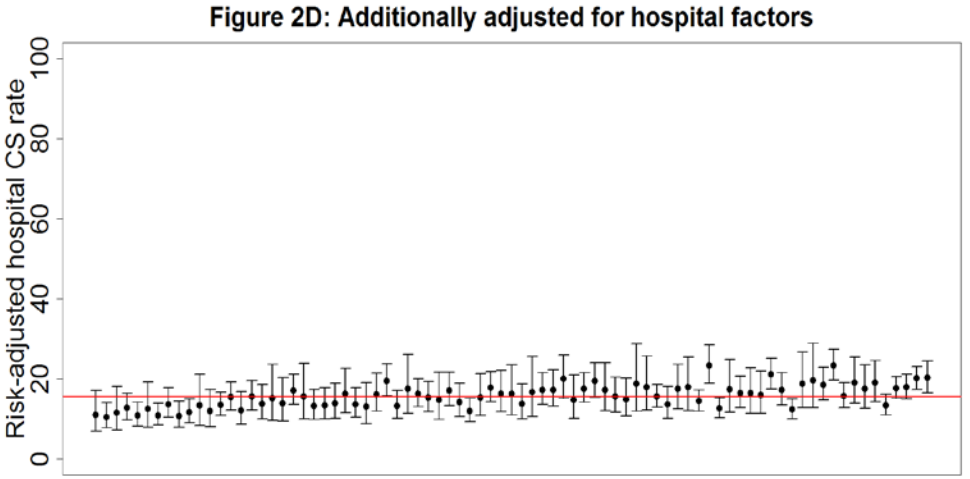
Solid horizontal lines indicate the mean risk-adjusted caesarean rates.

Figure 2: Hospital intrapartum caesarean rates among nulliparous women with a singleton, cephalic-presenting infant of ≥37 weeks gestation and spontaneous onset of labour



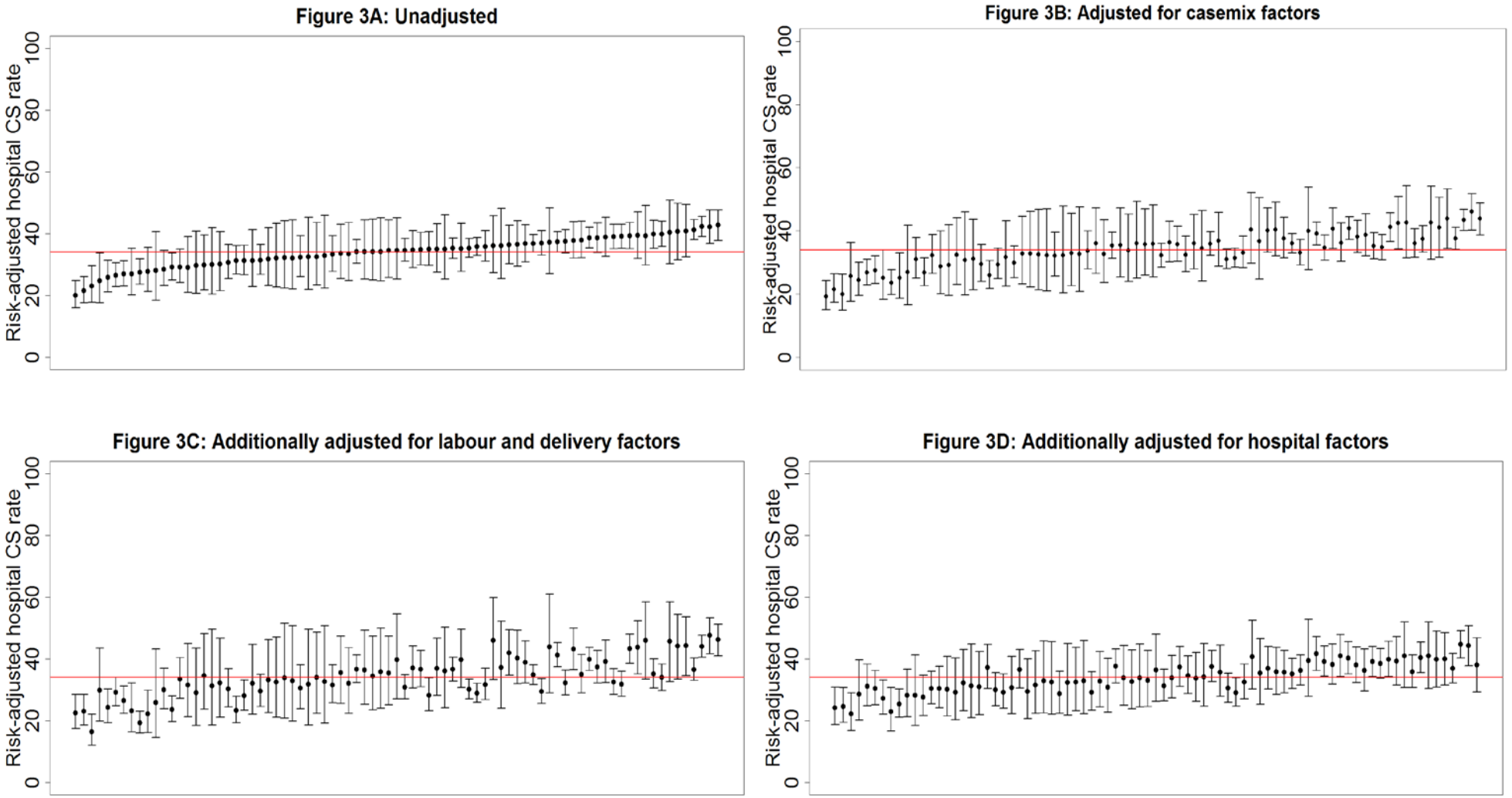






Solid horizontal lines indicate the mean risk-adjusted caesarean rates.

Figure 3: Hospital intrapartum caesarean rates among nulliparous women with a singleton, cephalic-presenting infant of ≥37 weeks gestation and induction of labour



Solid horizontal lines indicate the mean risk-adjusted caesarean rates.

Figure 4: Scatter plots of casemix adjusted severe morbidity and risk-adjusted hospital prelabour caesarean rates among nulliparous women with a singleton, cephalic-presenting infant of ≥37 weeks gestation

Figure 4A: Severe maternal morbidity

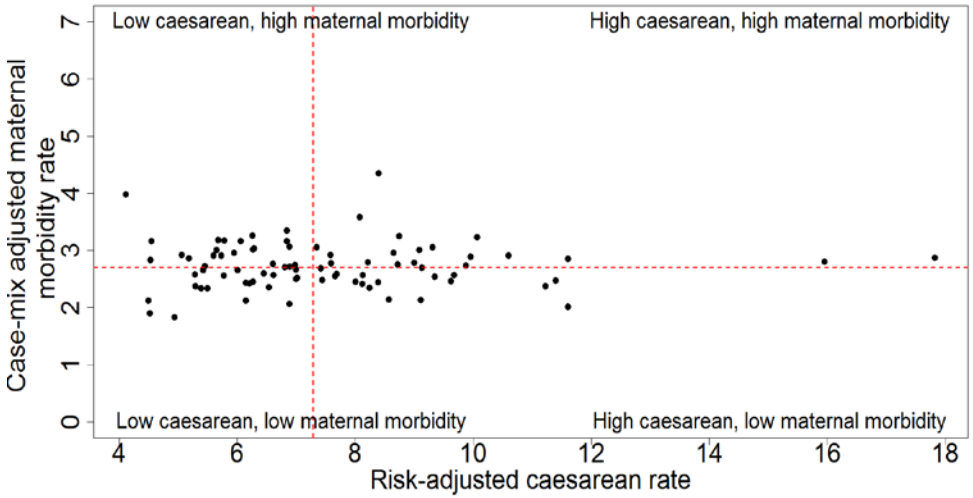
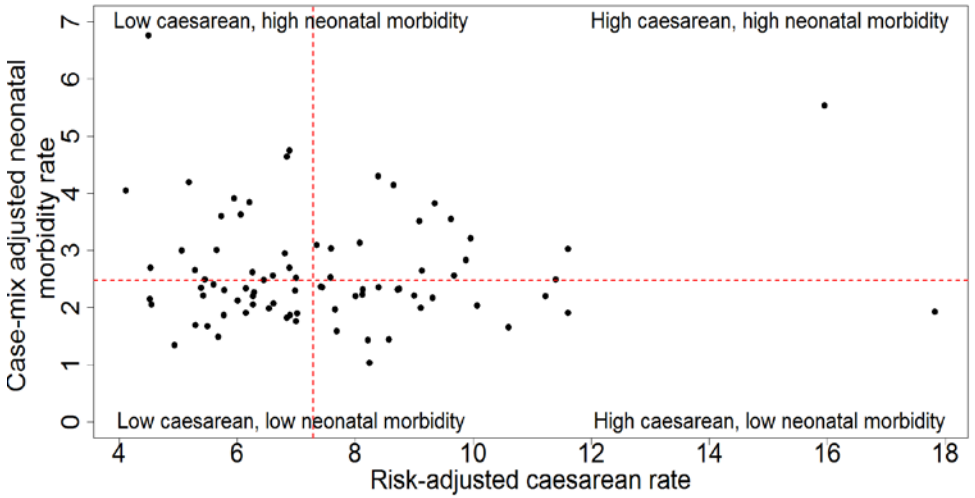


Figure 4B: Severe neonatal morbidity



Dashed lines indicate the mean risk-adjusted caesarean and morbidity rates.

Figure 5: Scatter plots of casemix adjusted severe morbidity and risk-adjusted hospital intrapartum caesarean rates among nulliparous women with a singleton, cephalic-presenting infant of ≥37 weeks gestation and spontaneous onset of labour

Figure 5A: Severe maternal morbidity

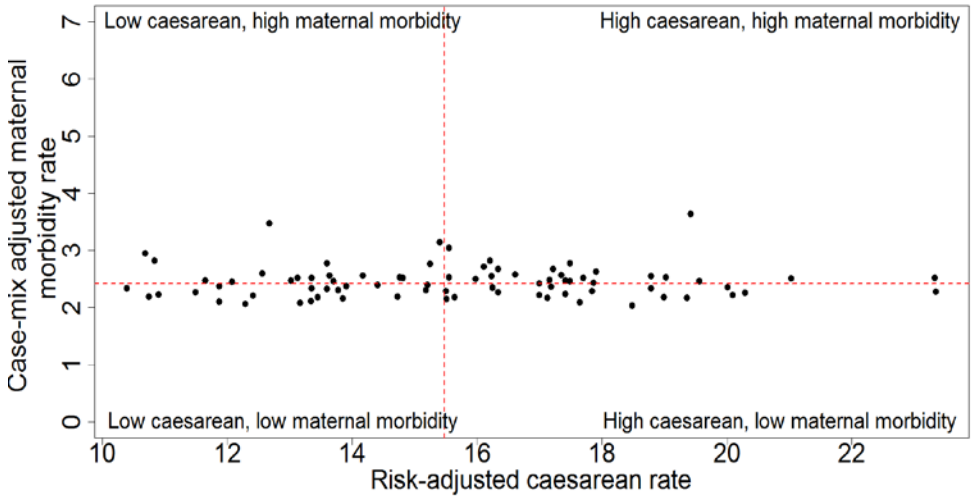
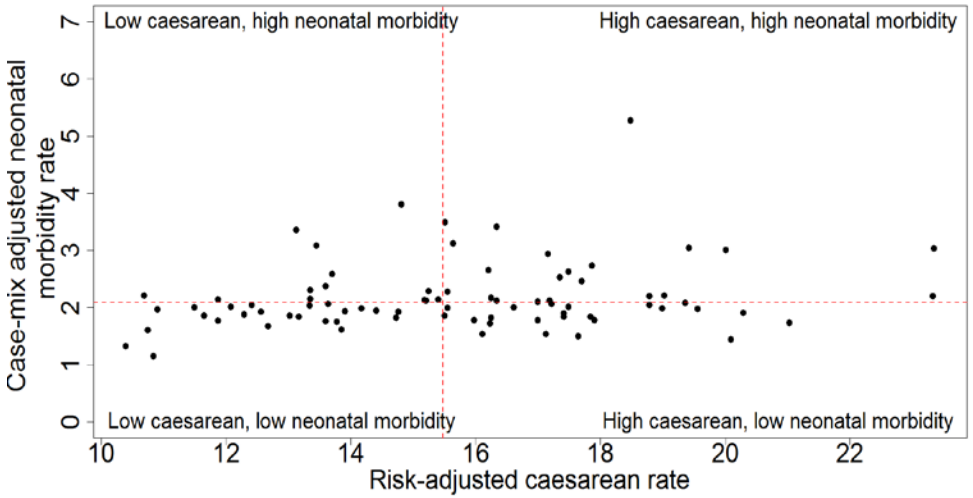


Figure 5B: Severe neonatal morbidity



Dashed lines indicate the mean risk-adjusted caesarean and morbidity rates.

Figure 6: Scatter plots of casemix adjusted severe morbidity and risk-adjusted hospital intrapartum caesarean rates among nulliparous women with a singleton, cephalic-presenting infant of ≥37 weeks gestation and induction of labour

Figure 6A: Severe maternal morbidity

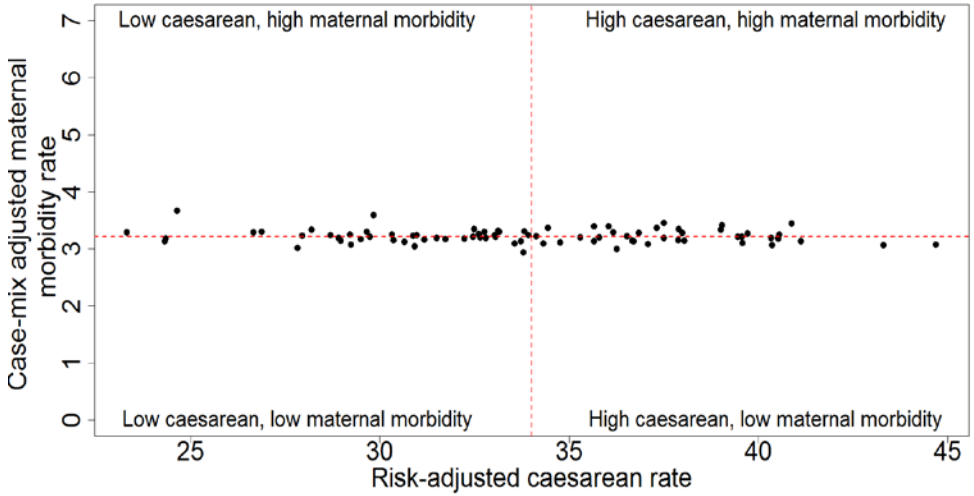
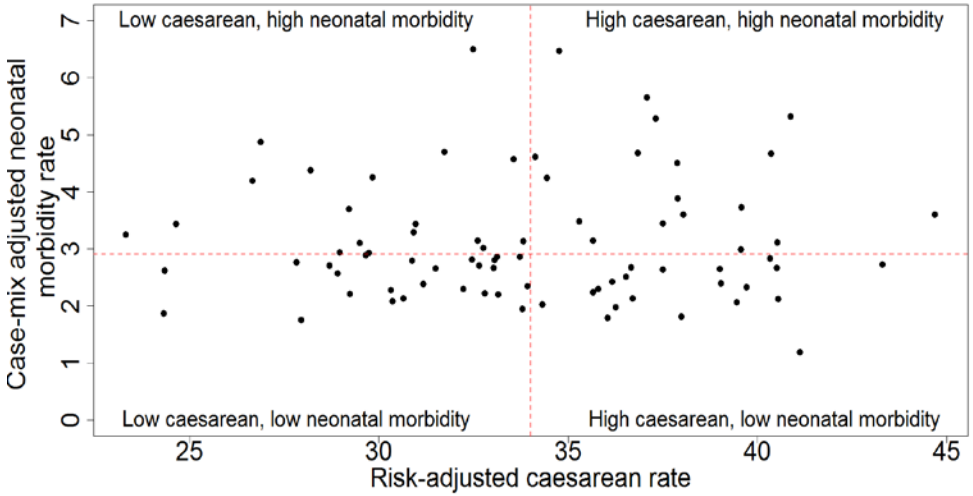


Figure 6B: Severe neonatal morbidity



Dashed lines indicate the mean risk-adjusted caesarean and morbidity rate

APPENDIX: Multilevel logistic regression modelling

Model formulation

Multilevel models are commonly used to analyse data that have a hierarchical structure as they explicitly take into account of the variability in outcome associated with each level of the hierarchy. This study involved analysis of 67,239 births nested within 81 NSW hospitals. Multilevel logistic regression with a random intercept for each hospital was used to examine variation in hospital caesarean rates (prelabour, or intrapartum caesarean following spontaneous labour or labour induction), denoted as y.[1]Consider a two-level random intercepts logistic regression model

$$y_{ij} = p_{ij} + \varepsilon_{ij},\ \log\left(\frac{p_{ij}}{1-p_{ij}}\right) = \beta_0 + u_{0j} + \sum_{k=1}^{K}\beta_k x_{ijk} + \sum_{l=1}^{L}\gamma_l z_{jl},$$

$$\varepsilon_{ij} \sim \text{Normal}\ (0, \sigma_\varepsilon^2) \quad \text{and} \quad u_{0j} \sim \text{Normal}\ (0, \sigma_{u0}^2),$$

$$\text{Cov}\ (\varepsilon_{ij}, u_{0j}) = 0 \quad \text{and} \quad \text{Cov}\ (y_{1j}, y_{2j}|x_{ijk}, z_{jl}) = \sigma_{u0}^2\ , \qquad (1)$$

where $i = 1, \ldots, I_j$ is the individual-level (Level 1) indicator, $j = 1, \ldots, J$ is the hospital-level (Level 2) indicator, p_{ij} denotes the probability of caesarean for woman i in hospital j, conditional on the individual-level risk factors x and hospital-level risk factors z, and $p_{ij}/(1-p_{ij})$ denotes the odds of caesarean for each woman. The terms β_k and γ_l are fixed regression coefficients corresponding to each risk factor. The term u_{0j} is a hospital-specific random effect, which represents the risk deviation from the overall average log odds of caesarean (β_0) for hospital j. The model assumes that the hospitals are randomly sampled from a normal population of hospitals with mean risk deviation zero and (between-hospital) variance σ_{u0}^2; each hospital j has its own intercept $\beta_0 + u_{0j}$. To account for fluctuation in caesarean rates for hospitals with a small number of births, a shrinkage factor was applied to the u_{0j}, moving them towards β_0. The resulting estimates are thus less variable.

Modelling strategy

For each Robson group, multilevel models were fitted in a stepwise manner.

Step 1: Unadjusted model

The first model unadjusted, including only hospital intercepts (Model A)

$$\log\left(\frac{p_{ij}}{1-p_{ij}}\right) = \beta_0 + u_{0j},$$

where σ^2_{u0} quantified the proportion of variation in hospital caesarean rates that was attributable to clustering (similarities of births) within hospitals.

Step 2a: Adjusting for individual-level factors

The second step included adjustment for casemix factors (represented by x)

$$\log\left(\frac{p_{ij}}{1-p_{ij}}\right) = \beta_0 + u_{0j} - \sum_{k=1}^{K} \beta_k x_{ijk}.$$

All casemix factors with $P < 0.10$ based on crude chi-squared test were initially included in the second model (Model B), and the overall least significant factor was progressively removed from the model until only factors significant at $P < 0.05$ or confounders (change in adjusted odds ratio of 10% or more) remained. All significant casemix factors were retained in the third model, and the same procedure was repeated for labour and delivery factors (Model C).

Step 2b: Identifying individual-level associations vary across hospitals

The second step was extended to allow individual-level associations vary from hospital to hospital, and this form a two-level random intercepts and slopes logistic regression model,

$$\log\left(\frac{p_{ij}}{1-p_{ij}}\right) = \beta_0 + u_{0j} - \sum_{k=1}^{K} (\beta_k + u_{1jk})\, x_{ijk}$$

$$\text{and } u_{0j}, u_{1jk} \sim \text{Normal}\left(\mathbf{0}, \begin{bmatrix} \sigma^2_{u0} & \rho\sigma_{u0}\sigma_{u1} \\ \rho\sigma_{u0}\sigma_{u1} & \sigma^2_{u1} \end{bmatrix}\right),$$

where u_{1jk} denotes the random slope for the risk factor x_k. The intercept-slope relationship is modelled via an unstructured variance-covariance matrix. This model further assessed

individual risk factors (one factor at a time) to identify individual-level associations that vary across hospitals.

Step 3: Additionally adjusting for hospital factors

Once all significant individual-level factors were determined, hospital factors were added into the model one at a time, and the hospital factors that most reduced the variation and were significant at $P < 0.10$ were included, representing the final model (Model D),

$$\log\left(\frac{p_{ij}}{1-p_{ij}}\right) = \beta_0 + u_{0j} + \sum_{k=1}^{K}\beta_k x_{ijk} + \sum_{l=1}^{L}\gamma_l z_{jl},$$

where z_{jl}'s is the l^{th} hospital factor and γ_l are fixed regression coefficients corresponding to each hospital factor.

The relative contribution of each step of adjustment to explaining the overall variation in hospital caesarean rates was quantified by calculating the difference between the variation of the preceding and current models, as a proportion of the preceding model's variation.

$$\% \text{ contribution} = \frac{(V_C - V_P)}{V_{UA}} \times 100,$$

where V_C denotes the variance of the current model, V_P denotes the variance of the preceding model and V_{UA} denotes the variance of the unadjusted model.

Fitting multilevel models using SAS GLIMMIX

All statistical analyses were performed using SAS (version 9.3; SAS Institute, Cary, North Carolina). One way to fit Model (4) using SAS GLIMMIX is

```
PROC SORT DATA=; BY hospital; RUN;
PROC GLIMMIX DATA= METHOD=QUAD (QPOINTS=12)
      CLASS x z;
      MODEL y(EVENT="Yes") = x z/DIST=BINARY LINK=LOGIT SOLUTION;
      RANDOM intercept/SUBJECT=hospital TYPE=VC SOLUTION;
      NLOPTIONS TECH=NRRIDG GCONV = 0;
RUN;
```

In this example, the variable hospital identifies the hospital from which the woman had a caesarean; thus it is on the SUBJECT statement. The MODEL statement specifies the caesarean outcome y and the fixed effects x and z, and the options DIST=BINARY and LINK=LOGIT specify that the outcome variable is binary distributed and the link function is logit. The option SOLUTION requests to print the solution for fixed and random effects. The RANDOM statement specifies intercept as the random effects, with hierarchical structure indicated in the SUBJECT option, i.e., births nested within hospitals. The maximum likelihood estimation was obtained by the most commonly used and least bias approach, namely adaptive Gauss-Hermite quadrature numerical approximation via the option METHOD=QUAD (with 12 quadrature points). The TECH option in the NLOPTIONS statement indicates the optimization technique in parameter estimation. Here we recommend the ridge-stabilised Newton Raphson algorithm (NRRIDG) for better convergence for binary distribution. Convergence of this optimization algorithm was assessed based on the relative gradient criterion GCONV=0 (the rate of change in the outcome versus change in the associated parameter estimates).

All fitted multilevel models were evaluated with *c* statistics to assess model discrimination, and the Hosmer-Lemeshow goodness-of-fit test to assess model calibration (the agreement between the observed caesarean rates and predicted probabilities). In addition, the distributions of the hospital random effects were examined to check if they were approximately normally distributed.

Calculation of risk-adjusted hospital caesarean rates

To illustrate the differences in hospital caesarean rates, we calculated and plotted the risk-adjusted hospital caesarean rates and 95% confidence intervals. The risk-adjusted hospital caesarean rates are defined as the ratio of the observed rate to the rate that would be expected given the characteristics of the women in a particular hospital. That is,

$$\frac{\text{Observed}}{\text{Expected}} \times \text{Statewide observed rate}.$$

In general, $\exp(u_{oj})$ (where u_{oj} is the hospital-specific random intercept) can be considered as an analog of the observed-over-expected measure. It is an approximation to the odds ratio of caesarean for hospital j relative to the statewide expected odds ratio of caesarean for hospital j, adjusting for the corresponding risk profile. Specifically, we have

$$\exp(u_{oj}) \approx \left(\frac{p_{oj}}{1-p_{oj}}\right) \Big/ \left(\frac{p_{ej}}{1-p_{ej}}\right),$$

where p_{oj} is the observed probability of caesarean for hospital j and p_{ej} is the expected probability of caesarean for hospital j. The risk-adjusted hospital caesarean rate can then be calculated by first converting hospital's odds ratio into a corrected relative risk (for common outcomes with prevalence > 10%)[2]

$$\text{Relative Risk}_{\text{corrected, j}} = \frac{\exp(\hat{u}_{oj})}{(1-p_{ej}) + \{p_{ej} \times \exp(\hat{u}_{oj})\}},$$

and then multiplying by the statewide observed caesarean rate. The 95% confidence intervals of the risk-adjusted hospital caesarean rates were calculated using the substitution method (the same relative risk formula was applied to the lower and upper confidence limits of the estimated $\hat{u}_{oj}$). The robustness of the confidence intervals was validated via bootstrap resampling for multilevel data.

REFERENCES

1. Leyland AH GH. Multilevel modelling of health statistics. Chichester, West Susex, UK: Wiley & Sons; 2001.

2. Zhang J, Yu KF. What's the relative risk? A method of correcting the odds ratio in cohort studies of common outcomes. *JAMA* 1998; **280**(19): 1690-1.

Table S1: Among all nulliparous women at term, adjusted odds ratios and 95% confidence intervals for hospital prelabour caesarean sections

All nulliparous women	Adjusted for casemix factors*		Additionally, adjusted for hospital factors*	
Casemix factors				
Maternal age (reference: 25–29 years)				
<20 years	0.74	[0.59,0.93]	0.75	[0.60,0.93]
20–24 years	0.75	[0.66,0.86]	0.76	[0.66,0.87]
30–34 years	1.37	[1.26,1.50]	1.37	[1.26,1.50]
35–39 years	2.18	[1.98,2.41]	2.19	[1.98,2.41]
≥40 years	4.08	[3.52,4.74]	4.10	[3.53,4.75]
Country of birth (reference: Australia)				
Asia	1.28	[1.16,1.40]	1.28	[1.17,1.41]
Others	1.18	[1.07,1.30]	1.18	[1.07,1.30]
ARIA+ Remoteness (reference: Major cities)				
Inner regional	1.25	[1.11,1.39]	1.26	[1.12,1.41]
Outer regional	1.16	[0.93,1.45]	1.16	[0.91,1.48]
Remote	0.93	[0.49,1.77]	0.94	[0.49,1.79]
Very remote	1.30	[0.53,3.16]	1.37	[0.56,3.34]
Smoking in pregnancy	1.34	[1.17,1.53]	1.35	[1.18,1.54]
Private obstetric care	2.76	[2.48,3.07]	2.64	[2.37,2.95]
Pregnancy hypertension	1.34	[1.21,1.47]	1.33	[1.20,1.46]
Cardiac diseases	1.84	[1.35,2.49]	1.83	[1.35,2.49]
Autoimmune disease	1.76	[1.22,2.53]	1.76	[1.22,2.54]
Inflammatory bowel disease	1.44	[0.84,2.47]	1.43	[0.83,2.46]
Placenta praevia	30.50	[24.9,37.3]	30.50	[24.9,37.3]

Placenta abruption	3.08	[2.09,4.54]	3.10	[2.11,4.57]
Assisted reproductive technology	1.19	[1.06,1.33]	0.84	[0.75,0.94]
Prior miscarriage	1.28	[1.14,1.43]	1.28	[1.14,1.43]
Birthweight percentiles (reference: 25.0–75.0)				
0·0–9·9	0.99	[0.88,1.10]	0.99	[0.88,1.11]
10·0–24·9	0.81	[0.75,0.88]	0.81	[0.75,0.88]
75·1–90·0	1.31	[1.19,1.45]	1.31	[1.19,1.45]
90·1–100·0	2.49	[2.24,2.78]	2.49	[2.24,2.78]
Estimated gestational age (reference: ≥40 weeks)				
37 weeks	3.75	[3.31,4.26]	3.75	[3.30,4.25]
38 weeks	4.70	[4.31,5.13]	4.70	[4.31,5.13]
39 weeks	3.01	[2.77,3.27]	3.01	[2.77,3.27]
Hospital factors				
Hospital type (reference: Primary training, urban, public)				
Secondary training, urban, public			0.97	[0.65,1.46]
Secondary training, rural, public			0.97	[0.62,1.50]
No training, urban, public			0.89	[0.40,1.95]
No training, rural, public			0.97	[0.60,1.56]
Private			2.03	[1.40,2.95]
Epidural rate			0.95	[0.91,1.00]
% caesarean with general anaesthetics			0.98	[0.97,1.00]

*Adjusted odds ratios and 95% confidence intervals for multilevel logistic regression with random hospital intercepts

Table S2: Among nulliparous women with spontaneous labour, adjusted odds ratios and 95% confidence intervals for hospital intrapartum caesarean sections

Spontaneous labour	Adjusted for casemix factors*		Additionally, adjusted for labour and delivery factors*		Additionally, adjusted for hospital factors	
Casemix factors						
Maternal age (reference: 25–29 years)						
<20 years	0.59	[0.51,0.68]	0.62	[0.53,0.71]	0.61	[0.53,0
20–24 years	0.70	[0.64,0.77]	0.72	[0.65,0.79]	0.72	[0.65,0
30–34 years	1.29	[1.20,1.39]	1.27	[1.18,1.37]	1.27	[1.18,1
35–39 years	1.85	[1.69,2.04]	1.89	[1.72,2.08]	1.90	[1.72,2
≥40 years	2.49	[2.05,3.02]	2.58	[2.11,3.16]	2.58	[2.11,3
Country of birth (reference: Australia)						
Asia	1.32	[1.22,1.44]	1.38	[1.27,1.50]	1.40	[1.28,1
Others	1.00	[0.91,1.09]	1.02	[0.93,1.12]	1.03	[0.94,1
Index of Education and Occupation (reference: 1st quintile)						
2nd quintile	1.01	[0.90,1.12]	1.06	[0.95,1.19]	1.04	[0.93,1
3rd quintile	1.09	[0.96,1.23]	1.19	[1.05,1.35]	1.15	[1.01,1
4th quintile	1.02	[0.88,1.17]	1.14	[0.99,1.32]	1.07	[0.92,1
5th quintile (Low education/occupation)	1.24	[1.08,1.43]	1.45	[1.25,1.68]	1.33	[1.15,1
Private obstetric care	1.07	[0.98,1.18]	0.99	[0.90,1.08]	0.98	[0.89,1
Chronic hypertension	1.54	[1.03,2.30]	1.41	[0.93,2.15]	1.41	[0.93,2
Pregnancy hypertension	1.64	[1.46,1.84]	1.56	[1.38,1.76]	1.55	[1.38,1
Autoimmune disease	1.51	[1.08,2.11]	1.52	[1.07,2.15]	1.53	[1.08,2
Placenta praevia	2.49	[1.58,3.94]	2.66	[1.66,4.28]	2.66	[1.66,4
Placenta abruption	10.30	[6.76,15.7]	13.30	[8.56,20.5]	13.20	[8.50,2

Assisted reproductive technology	0.83	[0.71,0.98]	0.85	[0.72,1.00]	0.85	[0.72,1
Birthweight percentiles (reference: 25.0–75.0)						
0.0–9.9	0.76	[0.69,0.84]	0.82	[0.74,0.90]	0.81	[0.73,0
10.0–24.9	0.72	[0.67,0.77]	0.73	[0.68,0.79]	0.73	[0.68,0
75.1–90.0	1.43	[1.31,1.56]	1.37	[1.25,1.50]	1.37	[1.25,1
90.1–100.0	2.43	[2.19,2.70]	2.35	[2.11,2.62]	2.34	[2.10,2
Labour and delivery factors						
Estimated gestational age (reference: ≥40 weeks)						
37 weeks			0.64	[0.55,0.74]	0.64	[0.55,0
38 weeks			0.73	[0.67,0.81]	0.74	[0.67,0
39 weeks			0.71	[0.66,0.76]	0.71	[0.66,0
Regional analgesia rate			3.97	[3.72,4.23]	4.02	[3.78,4
Hospital factors						
Hospital type (reference: Primary training, urban, public)						
Secondary training, urban, public					0.99	[0.75,1
Secondary training, rural, public					1.18	[0.87,1
No training, urban, public					2.10	[1.27,3
No training, rural, public					1.53	[1.16,2
Private					1.38	[1.05,1
% caesarean with general anaesthetics					1.01	[1.00,1
Instrumental birth rate					0.96	[0.92,0

*Adjusted odds ratios and 95% confidence intervals for multilevel logistic regression with random hospital intercepts

Table S3: Among nulliparous women with labour induction, adjusted odds ratios and 95% confidence intervals for hospital intrapartum caesarean sections

Labour induction	Adjusted for casemix factors*		Additionally, adjusted for labour and delivery factors*		Additionally, adjusted for hospital factors*	
Casemix factors						
Maternal age (reference: 25–29 years)	0.57	[0.50,0.66]	0.57	[0.50,0.66]	0.57	[0.49,0.65]
<20 years	0.73	[0.67,0.80]	0.74	[0.68,0.81]	0.74	[0.68,0.81]
20–24 years	1.22	[1.13,1.31]	1.22	[1.14,1.32]	1.23	[1.14,1.32]
30–34 years	1.65	[1.50,1.81]	1.67	[1.52,1.83]	1.67	[1.52,1.83]
35–39 years	2.12	[1.78,2.52]	2.17	[1.82,2.58]	2.16	[1.81,2.57]
≥40 years						
Country of birth (reference: Australia)						
Asia	1.32	[1.21,1.43]	1.42	[1.31,1.55]	1.43	[1.32,1.56]
Others	0.98	[0.90,1.07]	1.00	[0.92,1.10]	1.01	[0.92,1.10]
Private obstetric care	0.98	[0.90,1.06]	0.97	[0.89,1.06]	1.02	[0.93,1.11]
Pregnancy hypertension	1.25	[1.17,1.35]	1.30	[1.21,1.41]	1.30	[1.21,1.40]
Placenta praevia	1.69	[1.08,2.66]	1.84	[1.16,2.91]	1.82	[1.15,2.88]
Placenta abruption	6.98	[3.96,12.3]	8.25	[4.64,14.7]	8.23	[4.64,14.6]
Antenatal care	0.93	[0.82,1.06]	0.95	[0.84,1.08]	0.94	[0.83,1.07]
Birthweight percentiles (reference: 25.0–75.0)						
0.0–9.9	0.80	[0.73,0.88]	0.87	[0.79,0.96]	0.87	[0.79,0.96]
10.0–24.9	0.70	[0.65,0.75]	0.71	[0.66,0.76]	0.71	[0.66,0.76]
75.1–90.0	1.25	[1.14,1.36]	1.26	[1.15,1.38]	1.26	[1.15,1.38]
90.1–100.0	1.98	[1.78,2.19]	1.97	[1.78,2.18]	1.97	[1.77,2.18]
Labour and delivery factors						

Estimated gestational age (reference: ≥40 weeks)				
37 weeks	0.70	[0.61,0.80]	0.71	[0.62,0.81]
38 weeks	0.70	[0.64,0.77]	0.71	[0.65,0.78]
39 weeks	0.74	[0.69,0.80]	0.74	[0.69,0.80]
Regional analgesia rate	1.84	[1.73,1.95]	1.86	[1.75,1.98]
Induction with Prostaglandin	1.40	[1.32,1.48]	1.40	[1.32,1.48]
Hospital factors				
Hospital type (reference: Primary training, urban, public)				
Secondary training, urban, public			0.98	[0.75,1.28]
Secondary training, rural, public			1.20	[0.89,1.60]
No training, urban, public			1.62	[0.94,2.78]
No training, rural, public			1.27	[0.98,1.63]
Private			0.69	[0.53,0.90]

*Adjusted odds ratios and 95% confidence intervals for multilevel logistic regression with random hospital intercepts