Maternal and neonatal complications of fetal macrosomia: cohort study

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Abstract

Objective: To estimate risks of maternal and neonatal complications in pregnancies with macrosomia.

Method: This was a retrospective cohort study undertaken at a large maternity unit in United Kingdom between January 2009-December 2016. We compared the incidence of complications in pregnancies with macrosomia, defined by birthweight (BW)>4,000 g and severe macrosomia with BW>4,500 g, to those in pregnancies with normal BW 2,500-4,000 g. Regression analysis was undertaken to determine odds ratios (OR) [95% confidence interval (CI)] for pregnancy complications in macrosomic compared to normal BW group.

Results: The study population of 35,548 pregnancies included 4,522 (12.7%) with macrosomia, 643 (1.8%) with severe macrosomia and 31,026 (87.3%) with normal BW. In macrosomia group, adjusted OR was 3.07 (95%CI:1.64,2.01) for cesarean section for failure to progress, 2.40 (95%CI:1.95,2.96) for post-partum haemorrhage, 2.29 (95%CI:1.86,2.82) for sphincter injury, 10.37 (95%CI:8.57,12.55) for shoulder dystocia, 28.48 (95%CI:8.94,90.67) for brachial plexus injury, 32.33 (95%CI:3.76,278.15) for birth fractures and 4.40 (95%CI:2.20,8.82) for hypoxic-ischemic encephalopathy. The respective values for severe macrosomia were 4.32 (95%CI:3.05,6.13), 2.93 (95%CI:1.93,4.44), 3.12 (95%CI:1.92,5.08), 28.74 (95%CI:20.75,39.79), 73.92 (95%CI:15.05,363.16), 87.17 (95%CI:7.72,984.96) and 13.77 (95%CI: 5.16,36.75).

Conclusion: Macrosomia is associated with serious adverse perinatal outcomes. This study provides accurate estimates of risks to aid in pregnancy management.

Introduction

Fetal macrosomia is commonly defined as a neonatal birth weight (BW) of more than 4,000 g[1-3]. This cut-off corresponds to the 90th percentile at 40 weeks' gestation and therefore the prevalence of macrosomia is approximately 10% [3,4]. Fetal macrosomia is associated with maternal complications, such as emergency caesarean section (CS), post-partum hemorrhage (PPH), perineal trauma and neonatal complications, including shoulder dystocia, brachial plexus injury (OBPI), fracture of the humerus or clavicle and birth asphyxia [5-7]. However, there is considerable variation in the reported literature with regard to study design, sample size, type of complications reported and the lack of adjustment for confounding factors affecting the outcome measures, which introduces a significant bias in estimation of risks of these complications [5,6,8-14].

The objective of our study was to first, estimate absolute risks (AR) of maternal and neonatal complications in pregnancies with macrosomia; second, determine odds ratios (OR) for these complications, after adjusting for maternal and pregnancy characteristics, and third, determine AR and relative risks (RR) for macrosomic BWs for each complication as well as composite maternal and neonatal outcomes.

Materials and Methods

Study population

This was a retrospective cohort study undertaken in a large obstetric and neonatal unit at Medway NHS Foundation Trust, Gillingham in the United Kingdom during the period of 1st January 2009 to 31st December 2016. In our hospital, all women attend the Fetal Medicine Unit at 11-13 weeks' gestation for an ultrasound examination. In this visit we record maternal demographic characteristics and medical history on an electronic database (Viewpoint version 5.6; General Electric Company). Details of intrapartum care and information regarding neonatal care for those neonates admitted to the Neonatal Intensive Care Unit (NICU) are recorded in separate electronic databases (Euroking Maternity Software, Wellbeing software, Mansfield, United Kingdom; BadgerNet Neonatal Electronic Patient Record; Edinburgh, United Kingdom). A common database was constructed which contained information about maternal demographics, obstetric and medical history, antenatal, intrapartum and neonatal details by combining electronic searches of each of these databases. This study was a retrospective analysis of routinely collected pregnancy outcomes as part of routine clinical care and did not qualify for ethical approval.

Inclusion and exclusion criteria

The inclusion criteria were singleton pregnancies which booked and delivered at our hospital and birth of phenotypically normal neonates at ≥ 24 weeks' gestation. We excluded multiple pregnancies, miscarriages, stillbirths, terminations of pregnancy, those with major fetal defects and those that were lost to follow-up.

Patients meeting the inclusion criteria were subdivided according to BW into macrosomia (BW > 4000 g), normal (BW 2,500 - 4,000 g) and small (BW < 2,500 g). In the macrosomia group, a subgroup of severe macrosomia was identified (BW > 4,500 g). The small BW group was excluded from further analysis to avoid confounding effects on the rate of maternal and neonatal complications due to prematurity and low BW. Comparisons were made between the macrosomia and severe macrosomia groups with the normal BW group.

Outcome measures

Maternal complications: The maternal complications which were examined were rates of prolonged 1st and 2nd stage of labor, instrumental vaginal delivery, failed instrumental delivery requiring CS, emergency CS for any indication, CS for failure to progress (FTP) in labor, PPH and obstetric anal sphincter injury (OASIS). Prolonged 1st stage was defined as a duration of labor > 18 hours in nulliparous women and > 12 hours in multiparous women [15]. Prolonged 2nd stage was defined as duration > 2 hours in nulliparous women and > 1 hour in multiparous women [15]. Vaginal deliveries requiring either vacuum extraction or forceps were classified as instrumental births and those that required a CS following an unsuccessful application of either instrument were classified as failed instrumental deliveries [16]. Lucas classification was used to classify CS as an elective or emergency [17]. PPH was defined as an estimated blood loss (EBL) > 500 mL in the third stage of labor and was classified as minor (500-1000 mL), moderate (1001-2000 mL) or severe (> 2000 mL) [18]. OASIS encompassed third and fourth degree vaginal tears which involved a perineal injury to the anal sphincter complex and anorectal mucosa [19].

Neonatal complications: Shoulder dystocia was defined as a vaginal delivery that required additional obstetric manoeuvres to deliver the fetus after delivery of the head and failure of gentle traction [20]. We divided shoulder dystocia into two groups: the first group included any shoulder dystocia that required any manoeuvres and the second group included severe dystocia defined as need for internal obstetric manoeuvres, such as Wood's corkscrew, Rubin's or delivery of posterior arm [21]. OBPI resulting from a traction injury to the nerves during delivery was defined in the NICU following clinical examination by a senior neonatologist based on evidence of upper limb weakness or paralysis [22]. Birth fracture to the clavicle or humerus was diagnosed by an X-ray examination. Hypoxic-ischemic encephalopathy (HIE) was diagnosed when there was disturbed neurologic function with evidence of perinatal hypoxia reflected in either a 5-minute APGAR score < 5 or umbilical artery cord pH < 7.0 or base deficit > 12 mmol/L, supported by neuroimaging evidence of acute brain injury [23]. Hypoglycaemia was defined by neonatal serum glucose level < 2.6 mmol/L [24].

Composite of maternal and neonatal complications: We combined emergency CS for FTP, severe PPH and OASIS into one composite maternal group. Similarly, shoulder dystocia, birth fractures/OBPI and HIE were combined into one composite neonatal group. These complications are likely to occur together and therefore, an estimate of risk of any one of these adverse outcomes as a composite measure will potentially reduce overestimation of such risks.

Statistical analysis

Comparison of the maternal and pregnancy characteristics in the outcome groups was by the χ^2-square test and Fisher's exact test for categorical variables and Mann-Whitney U-test for continuous variables, respectively. Significance was assumed at 5% and Bonferroni correction was used to adjust for multiple comparisons where necessary.

Data for maternal and neonatal complications were entered into contingency tables and absolute risks (AR) for maternal and neonatal complications were estimated by determining the prevalence of these complications in macrosomia and severe macrosomia groups divided by the prevalence in the normal BW group. Logistic regression analysis was carried out in the case of each maternal and neonatal complication to estimate unadjusted univariate OR with 95% confidence intervals (CI). Multivariate OR (95% CI) were derived from logistic regression analysis with backward stepwise elimination by introducing maternal demographic factors, pregnancy and labor characteristics and macrosomia or severe macrosomia as a binary variable into the regression analysis. Prior to the regression analysis, the continuous variables, such as age, weight and height were centred by subtracting the arithmetic mean from each value to avoid effects of multicollinearity. The final model was a combination of variables that provided a

significant contribution to the prediction of the maternal or neonatal complications in the regression analysis. Estimates of AR were derived for severe maternal and neonatal complications and their respective composite adverse outcomes for BW from 4,000 to 6,000 g. We then derived RR for each BW category by dividing the AR in macrosomia by the AR in the normal BW group. Forest plots were constructed to express the OR (95% CI) for the macrosomia and severe macrosomia groups for maternal and neonatal complications. BW was regressed against the severe maternal and neonatal complications to graphically demonstrate the increase in risk of these complications with increasing BW.

The statistical package SPSS 24.0 (IBM SPSS Statistics for Windows, Version 24.0, Armonk, NY: IBM Corp; 2016) and MedCalc Statistical Software version 18.5 (MedCalc Software, Ostend, Belgium; http://www.medcalc.org; 2018) were used for data analyses.

Results

Study population

During the study period, 37,653 singleton pregnancies fulfilled the entry criteria, including 31,026 (82.4%) with normal BW, 4,522 (12.0%) with macrosomia and 2,105 (6.4%) with low BW. The macrosomia group included 643 (14.2%) with severe macrosomia. The group with small babies was not considered for further analysis.

The maternal and pregnancy characteristics in the study groups are compared in Table 1. In the macrosomic group, compared to the normal group, there was a higher median maternal age, weight and height, lower incidence of women of South Asian origin and cigarette smokers and higher incidence of gestational diabetes mellitus (GDM). With regard to pregnancy characteristics, in the macrosomic group, compared to the normal group, there was a higher median gestational age at delivery, EBL and a higher proportion of women undergoing induction of labor (IOL).

Maternal complications

In the macrosomia group, there was a significantly higher prevalence of all maternal complications (Table 2, Figure 1), with a 3-fold increased risk of CS for FTP and 2.5-fold increased risk of severe PPH and OASIS (Table 3, Figure 1). In the severe macrosomia group, there was a significantly increased risk for all adverse outcomes except for failed instrumental delivery, with a 4-fold increased risk of CS for FTP and a 3-fold increased risk for severe PPH and OASIS (Table 3, Figure 1). The risks of adverse maternal outcomes increased exponentially with increasing BW (Table 4, Figure 3).

Neonatal complications in the study groups

In the macrosomia group, there was a significantly higher prevalence of all neonatal complications (Table 2, Figure 2), with a 10-fold increased risk of shoulder dystocia, a 20-fold increased risk of severe shoulder dystocia, a 30-fold increased risk of BPI and birth fractures and a 2-fold increased risk of HIE (Table 3, Figure 2). In the severe macrosomia group, there was a significantly higher prevalence of all adverse outcomes, with a 70 to 80-fold increased risk of severe shoulder dystocia, OBPI and birth fractures and a 4-fold increased risk of HIE (Table 3; Figure 2). The risk of adverse neonatal outcomes increased exponentially with increasing BW after 4,000 g (Table 4, Figure 4).

Risk of composite adverse outcomes

The background risk of a composite maternal morbidity in the normal BW group was 6.0% and this increased from 10.4% at BW of 4,000 g, to 15.8% at BW of 4,500 g and 23.4% at BW of 5,000 g (Table 4). The background risk of composite neonatal morbidity in the normal BW group was 1.1% and this increased from 3.9% at BW of 4,000 g, to 12.6% at BW of 4,500 g and 33.6% at BW 5,000 g (Table 4).

Discussion

Principal findings of the study

The results of our study demonstrate that pregnancies with macrosomia are associated with a significantly increased risk for serious maternal and neonatal adverse outcomes including CS for FTP, severe PPH, OASIS, shoulder dystocia, OBPI, fractures and HIE. This increased risk of adverse outcomes is more substantial for the neonate than for the mother and the risk of complications is relatively low until 4,000 g increasing exponentially thereafter. The composite maternal adverse outcome increased from approximately, 2-fold at 4,000 g to 3-fold at 4,500 g, whereas the composite neonatal adverse outcome increased from 3-fold at 4,000 g to 10-fold at 4,500 g.

Strengths and limitations

The strengths of the study are first, examination of a large cohort of consecutively screened and delivered pregnancies in a large obstetric and neonatal unit; second, accurate ascertainment of maternal demographic and pregnancy characteristics to ensure there are no missing data; third, accurate ascertainment of maternal and neonatal adverse outcomes; fourth, estimation of risks for adverse outcomes after adjustment for maternal, pregnancy and labour characteristics; fifth, reporting of absolute and relative risks for adverse outcomes for BW ranging from 4,000 to 6,000 g to aid in antenatal counselling for provision of standardized information.

This is a single centre study and to a degree, the reported incidence of maternal and neonatal complications would be affected by the characteristics of the population and the protocols for antenatal and intrapartum care. However, there is no reason to believe that the absolute and relative risks of complications in the macrosomia group compared to those with a normal BW would vary substantially in different populations.

Comparison with other studies

Several studies have reported on the association of fetal macrosomia with adverse pregnancy outcomes but there is considerable variation in these studies with regard to design, sample size and types of adverse outcomes reported [5-14]. Some studies are case-control, some cohort studies and others population studies extracted from electronic databases without checking veracity of the reported outcome measures [5-7, 14]. The sample size in studies ranges from as small as 100 in some to more than 100,000 in others [6,11]. A significant potential bias is related to how the maternal and neonatal outcomes measures are obtained, which is reflected in the huge variation, not just the prevalence of these complications but also in the prevalence of macrosomia, which ranges from 0.9% in one study to 29.3% in another [14,25]. The studies largely report ARs or unadjusted OR based on prevalence of complications without adjusting for other factors that contribute to such complications with only a couple reporting adjusted OR [6,12]. Although, there is an appreciation of increased adverse outcomes for macrosomia, the variation in studies and biases resulting from such heterogeneity make it difficult to determine accurate risks of pregnancy complications from the reported literature. In our study, we examined the maternal and neonatal risks in a large unselected screened population in a cohort study with accurate determination of maternal and pregnancy characteristics, ascertaining the outcome

measures of complications accurately and reporting not just unadjusted risks but also multivariate OR by adjusting for other factors using regression analysis.

Conclusion

Our study confirms the association that pregnancies with macrosomia are associated with serious maternal and neonatal adverse outcomes. This study provides estimates of these risks that can be used for decisions on pregnancy management.

Conflicts of interest

No conflict of interest to report

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Table 1. Maternal and pregnancy characteristics in pregnancies with fetal macrosomia compared with those delivering non-macrosomic fetuses

Maternal and pregnancy characteristics	Normal BW BW 2500-4000 g (n=31,026)	Macrosomia	
		BW >4000 g (n=4,522)	BW >4500 g (n=643)
Maternal age in years, median (IQR)	28.6 (24.3-32.7)	29.4 (25.5-33.2)**	30.0 (26.1-34.0)**
Maternal weight in kg, median (IQR)	66.0 (58.0-78.0)	73.1 (63.9-86.0)**	77.0 (66.0-90.0)**
Maternal height in mt, median (IQR)	1.64 (1.60-1.68)	1.67 (1.62-1.70)**	1.68 (1.63-1.72)**
Racial origin			
Caucasian (Reference), n (%)	28,036 (90.4)	4,253 (94.1)	600 (93.3)
Afro-Caribbean, n (%)	999 (3.2)	122 (2.7)	21 (3.3)
South Asian, n (%)	1,475 (4.8)	94 (2.1)**	13 (2.0)*
East Asian, n (%)	132 (0.4)	15 (0.3)	2 (0.3)
Mixed, n (%)	384 (1.2)	38 (0.8)*	7 (1.1)
Conception			
Spontaneous (Reference), n (%)	30,796 (99.3)	4,485 (99.2)	638 (99.2)
Assisted conception, n (%)	230 (0.7)	37 (0.8)	5 (0.8)
Cigarette smoking, n (%)	5,736 (18.5)	462 (10.2)**	57 (8.9)**
History of medical disorders			
Chronic hypertension, n (%)	265 (0.9)	25 (0.6)	7 (1.1)
Pre-existing diabetes mellitus, n (%)	197 (0.6)	30 (0.7)	2 (0.3)
Gestational diabetes mellitus, n (%)	839 (2.7)	136 (3.0)	32 (5.0)**
Asthma, n (%)	1,826 (5.9)	243 (5.4)	37 (5.8)
Epilepsy, n (%)	199 (0.6)	22 (0.5)	1 (0.2)
Parity			
Nulliparous (Reference), n (%)	15,948 (51.4)	1,999 (44.2)	259 (40.3)
Parous without macrosomia, n (%)	13,419 (43.3)	1621 (35.8)**	179 (27.8)
Parous with macrosomia, n (%)	1,659 (5.3)	902 (19.9)**	205 (31.9)
Gestation at delivery, median (IQR)	39.6 (39.6-40.5)	40.6 (40.0-41.3)**	41.0 (40.2-41.4)**
Onset of labour			
Spontaneous (Reference), n (%)	20,728 (66.8)	2,751 (60.8)	343 (53.4)
No labour – elective delivery, n (%)	3,192 (10.3)	412 (9.1)	71 (11.0)
Induction of labour, n (%)	7,106 (22.9)	1,359 (30.1)**	229 (35.6)**
Mode of delivery			
Spontaneous vaginal (Reference), n (%)	20,832 (67.1)	2,781 (61.5)**	356 (55.4)
Instrumental vaginal delivery, n (%)	2,795 (9.0)	452 (10.0)	54 (8.4)
Elective caesarean section, n (%)	3,192 (10.3)	412 (9.1)	71 (11.0)
Emergency caesarean section, n (%)	4,207 (13.6)	877 (19.4)**	162 (25.2)
Estimated blood loss, median (IQR)	300 (250-500)	400 (300-600)**	450 (300-700)**

IQR = interquartile range;
Adjusted Bonferroni significance level p=0.025; ** p<0.0001; *p<0.01.

Table 2. Absolute risk of maternal and neonatal complications in pregnancies with macrosomia compared to those with normal birth weight (BW)

Complications	Normal BW BW 2500 – 4000 g (n=31,026)	Macrosomia	
		BW >4000 g (n=4,522)	BW >4500 g (n=643)
Maternal			
Prolonged 1st stage, n/N (%)	1,895/26,200 (7.2)	408/3,882 (10.5)**	63/513 (12.3)**
Prolonged 2nd stage, n/N (%)	1,533/24,838 (6.2)	306/3,694 (8.3)**	43/486 (8.8)*
Instrumental deliveries, n/N (%) [1]	2,795/23,627 (11.8)	452/3,233 (14.0)**	54/410 (13.2)
Failed instrumental deliveries, n/N (%) [2]	103/2,898 (3.5)	31/483 (6.4)*	3/57 (5.3)
Emergency CS – All, n/N (%) [3]	4,207/27,834 (15.1)	877/4,110 (21.3)**	162/572 (28.3)**
Emergency CS – FTP, n/N (%) [4]	832/24,459 (3.4)	295/3,528 (8.4)**	52/462 (11.3)**
Post-partum hemorrhage – All, n/N (%)	2,098/31,026 (6.7)	587/4,522 (13.0)**	99/643 (15.4)**
Post-partum hemorrhage – Severe, n/N (%)	344/31,026 (1.1)	137/4,522 (3.0)**	26/643 (4.0)**
Obstetric anal sphincter injury, n/N (%) [1]	478/23,627 (2.0)	121/3,233 (3.7)**	19/410 (4.6)**
Neonatal			
Shoulder dystocia – All, n/N (%) [1]	247/23,627 (1.0)	256/3,233 (7.9)**	70/410 (17.1)**
Shoulder dystocia - Severe, n/N (%) [1]	26/23,627 (0.1)	60/3,233 (1.9)**	24/410 (5.9)**
OBPI, n/N (%) [1]	4/23,627 (0.02)	12/3,233 (0.4)**	3/410 (0.7)**
Birth Fractures, n/N (%) [1]	1/23,627 (0.004)	5/3,233 (0.2)**	2/410 (0.5)**
HIE, n/N (%) [1]	21/23,627 (0.1)	13/3,233 (0.4)**	5/410 (1.2)**
Hypoglycemia, n/N (%)	413/31,026 (1.2)	77/4,522 (1.7)*	20/643 (3.1)**

CS=caesarean section; FTP=failure to progress; OBPI= Obstetric brachial plexus injury; HIE= Hypoxic ischaemic encephalopathy
Adjusted Bonferroni significance level p=0.025; ** p<0.0001; *p<0.01
Absolute risks calculated as a proportion of vaginal deliveries only[1], all instrumental deliveries attempted[2], all deliveries excluding elective CS[3], all deliveries excluding elective CS and those for fetal distress[4]

Table 3. Risk of maternal and neonatal complications in macrosomia pregnancies expressed as univariate and multivariate odds ratios (OR) with 95% confidence interval (CI)

Complications	Macrosomia (BW >4,000 g)		Severe macrosomia (BW >4,500 g)	
	Univariate OR (95% CI)	Multivariate OR (95% CI)	Univariate OR (95% CI)	Multivariate OR (95% CI)
Maternal				
Prolonged 1st stage	1.51 (1.35-1.69)	1.55 (1.37-1.76)	1.80 (1.37-2.35)	1.75 (1.29-2.37)
Prolonged 2nd stage	1.37 (1.21-1.56)	1.28 (1.12-1.48)	1.48 (1.07-2.03)	1.30 (0.92-1.83)
Instrumental deliveries	1.21 (1.09-1.35)	1.51 (1.33-1.71)	1.13 (0.85-1.51)	1.51 (1.09-2.10)
Failed instrumental deliveries	1.86 (1.23-2.82)	1.87 (1.24-2.85)	1.51 (0.46-4.90)	-
Emergency CS – All	1.52 (1.40-1.65)	1.54 (1.40-1.68)	2.22 (1.85-2.67)	2.12 (1.72-2.60)
Emergency CS – FTP	2.59 (2.26-2.97)	3.07 (2.62-3.59)	3.60 (2.77-4.84)	4.32 (3.05-6.13)
PPH – All	2.06 (1.87-2.27)	1.82 (1.64-2.01)	2.51 (2.02-3.12)	1.99 (1.59-2.50)
PPH – Severe	2.79 (2.28-3.41)	2.40 (1.95-2.96)	3.76 (2.50-5.64)	2.93 (1.93-4.44)
OASIS	1.88 (1.54-2.31)	2.29 (1.86-2.82)	2.35 (1.47-3.76)	3.12 (1.92-5.08)
Neonatal				
Shoulder dystocia – All	8.14 (6.81-9.73)	10.37 (8.57-12.55)	19.49 (14.64-25.95)	28.74 (20.75-39.79)
Shoulder dystocia - Severe	17.17 (10.82-27.24)	20.27 (12.62-32.56)	56.44 (32.12-99.19)	75.64 (41.28-138.62)
OBPI	22.00 (7.09-68.26)	28.48 (8.94-90.67)	45.53 (9.71-195.12)	73.92 (15.05-363.16)
Birth Fractures,	36.56 (4.27-313.33)	32.33 (3.76-278.15)	115.81 (10.48-1279.77)	87.17 (7.72-984.96)
HIE	4.54 (2.27-9.07)	4.40 (2.20-8.82)	13.88 (5.21-36.99)	13.77 (5.16-36.75)
Hypoglycemia	1.28 (1.01-1.64)	2.04 (1.54-2.69)	2.38 (1.51-3.75)	4.17 (2.50-6.94)

CS=caesarean section; FTP=failure to progress; PPH= Post-partum haemorrhage; OASIS=Obstetric anal sphincter injury; OBPI= Obstetric brachial plexus injury; HIE= Hypoxic ischaemic encephalopathy; CI=confidence interval.

Table 4. Estimates of increased risk for maternal and neonatal complications in pregnancies with fetal macrosomia compared to those without macrosomia* expressed as absolute risk (percentages) and relative risks (RR)

BW (g)	Maternal complications, [%, (RR)]				Neonatal complications, [%, (RR)]			
	CS-FTP	PPH-severe	OASIS	Composite	SD	BPI	HIE	Composite
Background*	3.4 (1.0)	1.1 (1.0)	2.0 (1.0)	6.0 (1.0)	1.0 (1.0)	0.01 (1.0)	0.1 (1.0)	1.1 (1.0)
4000	6.3 (1.8)	2.1 (1.9)	3.2 (1.6)	10.4 (1.7)	3.7 (3.7)	0.1 (7.7)	0.2 (2.2)	3.9 (3.6)
4100	6.9 (2.0)	2.3 (2.1)	3.4 (1.7)	11.3 (1.9)	4.8 (4.8)	0.1 (10.0)	0.2 (2.4)	5.0 (4.5)
4200	7.7 (2.3)	2.5 (2.3)	3.7 (1.9)	12.3 (2.1)	6.1 (6.1)	0.1 (12.9)	0.3 (2.6)	6.3 (5.8)
4300	8.5 (2.5)	2.7 (2.5)	4.0 (2.0)	13.4 (2.2)	7.8 (7.8)	0.2 (16.7)	0.3 (28.0)	8.0 (7.3)
4400	9.4 (2.8)	3.0 (2.7)	4.3 (2.2)	14.6 (2.4)	9.9 (9.9)	0.2 (21.7)	0.3 (3.0)	10.1 (9.1)
4500	10.3 (3.0)	3.3 (3.0)	4.7 (2.3)	15.8 (2.6)	12.4 (12.4)	0.3 (28.1)	0.3 (3.3)	12.6 (11.4)
4600	11.4 (3.4)	3.6 (3.3)	5.0 (2.5)	17.2 (2.9)	15.6 (15.6)	0.4 (36.5)	0.4 (3.6)	15.6 (14.2)
4700	12.6 (3.7)	4.0 (3.6)	5.4 (2.7)	18.6 (3.1)	19.3 (19.3)	0.5 (47.2)	0.4 (3.9)	19.2 (17.5)
4800	13.8 (4.1)	4.4 (3.4)	5.8 (2.9)	20.1 (3.4)	23.7 (23.7)	0.6 (61.2)	0.4 (4.2)	23.4 (21.3)
4900	15.2 (4.5)	4.8 (4.4)	6.3 (3.1)	21.7 (3.6)	28.8 (28.8)	0.8 (79.2)	0.5 (4.6)	28.3 (25.7)
5000	16.7 (4.9)	5.3 (4.8)	6.8 (3.4)	23.4 (3.9)	34.4 (34.4)	1.0 (102.5)	0.5 (5.0)	33.6 (30.6)
5100	18.2 (5.4)	5.8 (5.3)	7.3 (3.6)	25.2 (4.2)	40.5 (40.5)	1.3 (132.6)	0.5 (5.4)	39.5 (35.9)
5200	19.9 (5.9)	6.4 (5.8)	7.8 (3.9)	27.1 (4.5)	47.0 (47.0)	1.7 (171.3)	0.6 (5.9)	45.6 (41.5)
5300	21.7 (6.4)	7.0 (6.4)	7.4 (4.2)	29.0 (4.8)	53.5 (53.5)	2.2 (221.1)	0.6 (6.4)	51.9 (47.2)
5400	23.7 (7.0)	7.7 (7.0)	9.1 (4.5)	31.1 (5.2)	59.9 (59.9)	2.9 (285.0)	0.7 (6.9)	58.2 (52.9)
5500	25.7 (7.6)	8.4 (7.6)	9.7 (4.9)	33.2 (5.5)	66.0 (66.0)	3.7 (366.5)	0.8 (7.5)	64.1 (58.3)
5600	27.9 (8.2)	9.2 (8.3)	10.4 (5.2)	35.4 (5.9)	71.6 (71.6)	4.7 (470.4)	0.8 (8.2)	69.7 (63.4)
5700	30.1 (8.9)	10.0 (9.1)	11.2 (5.6)	37.6 (6.3)	76.6 (76.6)	6.0 (601.7)	0.9 (8.8)	74.8 (68.0)
5800	32.5 (9.6)	11.0 (10.0)	12.0 (6.0)	39.9 (6.7)	81.0 (81.0)	7.7 (766.9)	1.0 (9.6)	79.2 (72.0)
5900	34.9 (10.3)	12.0 (10.9)	12.9 (6.4)	42.3 (7.1)	84.7 (84.7)	9.7 (972.6)	1.0 (10.4)	83.1 (75.5)
6000	37.5 (11.0)	13.0 (11.9)	13.8 (6.9)	44.7 (7.5)	87.8 (87.8)	12.3 (1226.6)	1.1 (11.3)	86.3 (78.5)

Em CS- FTP = Emergency caesarean section for failure to progress; PPH = post-partum haemorrhage; OASIS = obstetric anal sphincter injury; SD = Shoulder dystocia; BPI = brachial plexus injury; HIE = hypoxic ischaemic encephalopathy
* Background risk of complications in neonates with birthweight between 2,500 and 4,000g

Figure legends

Figure 1. Forrest plot of odds ratios (OR) with 95% confidence intervals (CI) for maternal complications in pregnancies with macrosomia (grey diamonds) and severe macrosomia (black diamonds) (CS: cesarean section; FTP: Failure to progress; PPH: post-partum hemorrhage; OASIS: obstetric anal sphincter injuries)

Figure 2. Forrest plot of odds ratios (OR) with 95% confidence intervals (CI) for maternal complications in pregnancies with macrosomia (grey diamonds) and severe macrosomia (black diamonds) (HIE: hypoxic ischaemic encephalopathy)

Figure 3. Risk of maternal complications of macrosomia plotted against birth weight. (Cesarean section for failure to progress – [—], obstetric anal sphincter injury – [ ] and severe post-partum hemorrhage – [····]).

Figure 4. Risk of neonatal complications of macrosomia plotted against birth weight. (Shoulder dystocia – [——], Obstetric brachial plexus injury – [----] and birth fractures – [····]).