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Trends and determinants of increasing caesarean sections from 2010 to 2013 in a prospective population-based registry in eastern rural Maharashtra, India

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ABSTRACT

Objective Our objective was to describe trends in caesarean section (CS) rates, characteristics of women delivering by CS, reasons for CS and impact of CS on perinatal mortality, in a rural Indian population.

Design Secondary data analysis using a prospective population-based registry.

Setting Four districts in Eastern Maharashtra, India, 2010 to 2013.

Participants 39 026 pregnant women undergoing labour and delivery.

Main outcomes CS, single most likely reason, perinatal mortality.

Results Overall, 20% of the women delivered by CS. Rates increased from 17.4% in 2010 to 22.7% in 2013 (p<0.001) with an absolute risk increase from 1% to 5% during this time-period. Women aged 25+ years old, being nulliparous, having at least a secondary school education, a body mass index 25+ and a multiple gestation pregnancy were more likely to deliver by CS. Perinatal mortality was higher among babies delivered vaginally than those delivered by CS (4.5% vs 2.7%, p<0.001). Prolonged and obstructed labour as the reported reason for CS increased over time for both nulliparous and multiparous women (p<0.001), and 6% to 10% women had no clear reason for CS. Perinatal mortality was higher among babies born vaginally than those delivered by CS (adjusted OR: 0.65, 95% CI 0.56 to 0.76, p<0.001).

Conclusion Rates of CS increased over time in rural Maharashtra, exceeding WHO recommendations. Characteristics associated with CS and outcomes of CS were similar to previous reports. Further studies are needed to ensure accuracy of reported reasons for CS, why obstructed and prolonged labour leading to CS is increasing in this population and what leads to CS without a clear indication. Such information may be helpful for implementing the Indian Government mandate that no CS be performed without strict medical indications, while ensuring that the overall CS rates are appropriate.

Trial registration number NCT01073475.

INTRODUCTION

In 1985, a WHO report stated that there was 'no justification for any region to have a caesarean section (CS) rate higher than 10%

Strengths and limitations of this study

► Large, population-based pregnancy registry of mode of delivery, caesarean section (CS) rates and birth outcomes in rural central India from 2010 to 2013 before the 2017 Government of India mandate that CS should not be performed unless medically indicated.

► Follow-up rates for perinatal mortality and other maternal and neonatal outcomes >99%.

► Reasons for CS collected within 7 days of birth, but only the single most important reason for CS was available.

► Information on whether the CS was elective or for an emergency was not available.

to 15%'.[1] Recently, in response to numerous reports of increasing CS rates globally,[2] the WHO has revisited these recommendations and concluded that: CS done for medically indicated reasons save maternal and infant lives; CS rates above 10% are not associated with decreased maternal and neonatal mortality; CS can cause significant maternal morbidity and mortality, particularly where safe surgery is not available; CS should be provided to women in need and more research is needed to understand the impact of CS on a range of maternal and neonatal outcomes.[3]

Betrán *et al*[4] studied trends in CS rates in 150 countries between 1990 and 2014 using cross-sectional data from Demographic and Health Surveys (DHS), Multiple Indicator Cluster Surveys and European Health for All Database and Government Vital Statistics Registries. They found that CS rates increased by 4.4% every year since 1990 and in 2014 CS rates globally were 18.6% (range from 1.4% to 56.4%), exceeding the WHO recommendations. In a 2013 analysis of disparities in CS rates using DHS data from 26 countries

in South Asian and sub-Saharan Africa, the poorest 20% of the population consistently had CS rates of less than 2%, particularly concentrating in the 'rural poor', while the rate in 'urban rich' in South Asia was 15%.[5] These results were confirmed by the Eunice Kennedy Shriver National Institute of Child Health and Human Development's (NICHD's) Global Network's (GN) rural population-based Maternal and Newborn Registry (MNHR) between 2010 and 2015.[6]

The effect of CS on neonatal mortality remains controversial and data on perinatal mortality are sparse. Ye *et al* recently reported on neonatal mortality rates following CS in 159 countries using data from DHS and concluded that CS rates higher than 10% did not decrease neonatal mortality rates globally.[7] The authors did find a benefit to neonatal mortality when CS were lower than 10%. Molina *et al* analysed 2012 data from 54 WHO member states and found a benefit to neonatal mortality when CS rates were up to 19.4 per 100 live births, but not when CS rates were greater than 19.4.[8]

Since ~20% of the world's newborns are born in India, CS trends in India are particularly important globally, as well as within India. The most recent Indian National Family Health Survey 2015–2016 (which also collects cross-sectional data, similar to the DHS) conducted in 15 Indian states and union territories reported a CS rate of 17.1% and drew attention to CS rates in private health facilities — 41.0% versus 11.9% in government hospitals.[9] In private facilities this rose from 27.8% and in public facilities decreased from 15.2% reported in 2005 to 2006.[10] In 2017, the Government of India mandated that no CS be performed without strict medical indications. A new 20-point guideline for the strict auditing and monitoring of CS surgeries in public and private hospitals is under consideration.[11] Although many questions remain about its implementation and its ability to ensure that CS are performed only when indicated. Regardless, it will be important to evaluate its impact in urban and rural populations in India.

The Indian National Family Health Survey does not collect data on the single most likely reason for having a CS. However, as NICHD's Global Network (includes Nagpur site) has been conducting a population-based registry of pregnant women and their neonates since 2009 that includes reason for caesarean section, it is suitable to explore trends in CS rates over time prior to implementation of the Indian Government guidelines.[12] The Nagpur site includes pregnant women in the catchment area of 20 primary health centres in rural areas surrounding the city. Our objectives were to (1) describe characteristics of the women delivering by CS and identify the single most likely reason for CS, (2) evaluate trends over time in the single most likely reason for CS and to (3) evaluate the impact of CS on perinatal mortality. The added value of this paper not previously reported in the prior GN paper is the analysis of reasons for CS and perinatal mortality data collected prospectively over time.

METHODS

Study population for the Maternal and Newborn Health Registry

We used prospectively collected data from pregnant women and their babies enrolled in the Maternal and Neonatal Health Registry in eastern Maharashtra state, near Nagpur, India. This site is included in the Global Network for Women's and Children's Health Research, a network of institutions, funded by the Eunice Kennedy Shriver National Institute of Child Health and Human Development in the USA, which conducts research to improve maternal and newborn outcomes in rural areas.

Each GN site includes the population from 8 to 20 predetermined geographical areas or clusters. In the Nagpur site, each cluster is defined as the catchment area of a primary healthcare centre (PHC) where 300 to 500 births are expected annually. The Nagpur site includes 20 PHCs in the Nagpur, Bhandara, Wardha and Chandrapur districts. The Nagpur MNHR was established with the collaboration of the state public health systems. The objective of the MNHR is to enrol pregnant women early in their gestation and obtain data on pregnancy outcomes for all women, regardless of the place of birth (home, health centre or hospital). Pregnant women are enrolled early during their pregnancy and are followed through 6 weeks after birth to obtain outcomes for mother and the baby. Follow-up rates exceed 99%. The MNHR data was obtained from interviews with the mothers conducted by auxiliary nurse midwives (ANMs) trained to question and record the information on the data collection forms as well as medical information from multiple sources completed by medical officers at the PHCs involved in the MNHR. The medical officers were trained to complete the study forms and attended monthly group meetings to review study progress and data collection procedures throughout the registry data collection period. Sources of information used by the medical officers included records of antenatal and postnatal care and deliveries in the PHC or its sub-centres as well as other facility discharge summaries given to the woman and the medical officer, which included the single most important reason for CS when the woman had delivered by CS. The methods of the registry have been published previously.[12]

Our data collection instruments include mode of delivery (vaginal, vaginal assisted and CS) and details of maternal conditions relating to labour and delivery (including obstructed or prolonged labour, major antepartum or postpartum haemorrhage, hypertensive disease, preeclampsia or eclampsia, breech or oblique lie).[12] For women who underwent CS, we collected data on the single most likely reason for CS which included the previous list and foetal distress, oligohydramnios and polyhydramnios, uterine rupture, previous CS, etc.[12] Potential antenatal maternal factors for having a CS included mother's age (<25 years vs 25+ years), parity (nulliparous vs multiparous), mother's education (none/primary, secondary, university), maternal body mass index (BMI) (kg/m^2) in categories (<18.5, 18.5 to
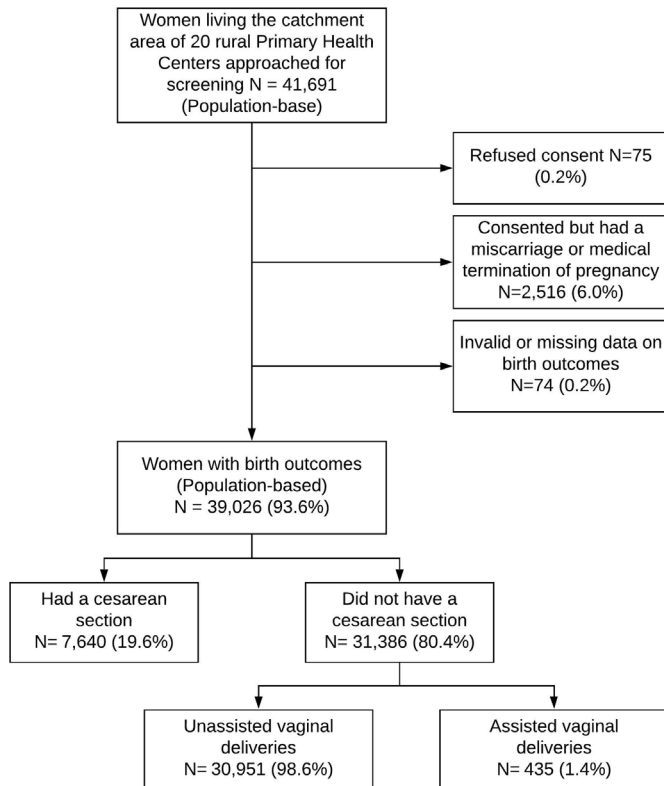
Figure 1 Recruitment and flow diagram for the population-based Global Network Maternal and Newborn Health Registry and population-based secondary data analysis for the caesarean section study, 2010-2013.

24.9, 25.0+), anaemia (none (haemoglobin ≥11 g/dL), mild (haemoglobin 10.0 to 10.9 g/dL), moderate/severe (haemoglobin ≤10 g/dL)), multiple gestation (yes/no) and gestational age (preterm (<37 weeks)/full-term (≥37 weeks)). The data collection forms included outcomes for mothers and their babies. Women and their babies were followed through day 42 postpartum for maternal death at any time during pregnancy, labour and delivery. Similarly, the pregnancy was followed up for stillbirths (foetus with no signs of life at birth from 20 weeks of gestation) and neonatal mortality through day 28 of life. Perinatal mortality was defined as a stillbirth or neonatal mortality within 7 days of delivery.

Ethical approvals for the MNHR and trial registration number
A Data Monitoring Committee appointed by the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development of the US National Institutes of Health, reviewed MNHR data bi-annually. The MNHR is registered at ClinicalTrials.gov (NCT01073475).Pregnant women intending to deliver in the study communities or affiliated hospitals were informed about the study and invited to participate in the MNHR and enrolled if they provided a written consent for trial participation.

Study population for the secondary data analysis
We included women who had previously been determined to be eligible and consented to participate in the

MNHR from January 2010 to December 2013, when all study data for complete years were collected using a single version of the MNHR data collection forms. Eligibility criteria were minimal because the intent was to enrol as many women as possible in the catchment area of each cluster to obtain a population-based study sample. Inclusion criteria for the MNHR included residing in MNHR clusters in Nagpur and intending to deliver in the study cluster, but included women who were transferred outside the cluster for delivery because that could not be determined at enrolment. Women who declined to consent in the MNHR were excluded (<0.2%). For this study, our only additional exclusion criteria for the women who had previously enrolled in the MNHR were women who had a miscarriage or medical termination of pregnancy or had missing data on mode of delivery and birth outcomes as shown in figure 1.

Study outcomes
The first objective of the study was to identify characteristics of the women undergoing CS and the single most likely reason for CS. The second objective was to test the hypothesis that the single most likely reason for CS changed over time (2010 to 2013). The third objective tested the hypothesis that infants delivered by CS had a lower risk of overall perinatal mortality. The study outcomes were: the overall proportion of CS and the rates per year, the single most likely reason for CS per year and perinatal mortality.

Statistical analysis
The overall and annual trends in CS rates were measured as the proportion of women who underwent CS among all women with birth outcomes at a gestation of 20 weeks or more. We obtained unadjusted and adjusted (for all variables described earlier) relative risks (RR) and 95% CIs from Poisson regression models assessing the relationship of the characteristics with delivering by CS. Since we were concerned about the possible impact of mother's age and parity on CS, we included an interaction between these variables in our models. We also obtained absolute risks (AR) with 95% CI from the adjusted models. Trends of CS rates over time (years) were tested by including a continuous variable to indicate time in the models. Similar models were used to evaluate the relationship of CS with perinatal mortality. Further, we obtained the distribution of reasons for CS over time separately among the nulliparous and multiparous women stratified by age. We tested for the trend in reasons for CS over time in the nulliparous and multiparous women using the Cuzick's test. All analyses adjusted for the clustering of women within PHCs with generalised estimating equations approach and were performed in STATA 13.1 (StataCorp. 2014. Stata Statistical Software: Release 13.1 MP4.StataCorp LP: College Station, Texas, USA). A two-sided p<0.05 was considered significant.

Patient and public involvement
Patients were not involved in the recruitment and conduct of this study. ANMs previously conducted community

Table 1 Unadjusted and adjusted results obtained from regressions assessing the relationship of characteristics of the pregnant women with mode of delivery

Characteristic	Mode of delivery		RR (95% CI)		
	CS n=7640 (19.6%) N (row %)	Vaginally n=31 386 (80.4%)	Unadjusted*	Adjusted†	Adjusted† AR (95% CI)
Time in years					
2010	1754 (17.4)	8313 (82.6)	Referent	Referent	Referent
2011	1749 (18.3)	7798 (81.7)	1.05 (0.98 to 1.12)	1.03 (0.97 to 1.10)	0.01 (−0.01 to 0.02)
2012	1889 (19.9)	7618 (80.1)	1.14 (1.07 to 1.22)	1.11 (1.04 to 1.19)	0.02 (0.01 to 0.03)
2013	2248 (22.7)	7657 (77.3)	1.31 (1.23 to 1.40)	1.26 (1.19 to 1.35)	0.05 (0.04 to 0.06)
Mother's age (years)					
<25	5026 (18.9)	21619 (81.1)	Referent	Referent	Referent
25+	2614 (21.1)	9767 (78.9)	1.11 (1.06 to 1.17)	1.17 (1.09 to 1.26)	-
Parity					
Nulliparous	4463 (23.8)	14273 (76.2)	1.51 (1.44 to 1.59)	1.46‡ (1.37 to 1.55)	-
Multiparous	3177 (15.7)	17113 (84.3)	Referent	Referent	Referent
Mother's age (years)/parity					
<25, multiparous	1437 (14.06)	8787 (85.94)	Referent	Referent	Referent
<25, nulliparous	3589 (21.86)	12832 (78.14)	-	-	-
25+, multiparous	1740 (17.29)	8326 (82.71)	-	-	-
25+, nulliparous	874 (37.75)	1441 (62.25)	1.40 (1.27 to 1.55)	1.31 (1.18 to 1.44)	0.09 (0.06 to 0.12)
Mother's education§					
None/primary	1058 (13.3)	6912 (86.7)	Referent	Referent	Referent
Secondary	4325 (18.7)	18860 (81.3)	1.44 (1.34 to 1.54)	1.38 (1.28 to 1.48)	0.05 (0.04 to 0.06)
University	2245 (28.7)	5567 (71.3)	2.17 (2.00 to 2.36)	1.87 (1.73 to 2.03)	0.12 (0.11 to 0.14)
BMI categories (kg/m²)§					
<18.5	2220 (16.4)	11289 (83.6)	0.83 (0.79 to 0.87)	0.85 (0.80 to 0.89)	−0.03 (−0.04 to −0.02)
18.5–24.9	4878 (20.3)	19161 (79.7)	Referent	Referent	Referent
25.0+	537 (37.2)	905 (62.8)	1.81 (1.65 to 1.99)	1.57 (1.43 to 1.72)	0.12 (0.09 to 0.15)
Anaemia (haemoglobin g/dL)					
None (≥11.0)	896 (26.5)	2486 (73.5)	Referent	Referent	Referent
Mild (10.0–10.9)	3261 (20.0)	13024 (80.0)	0.74 (0.69 to 0.80)	0.84 (0.78 to 0.91)	−0.04 (−0.05 to −0.02)
Moderate or severe (<10.0)	3483 (18.0)	15876 (82.0)	0.66 (0.61 to 0.72)	0.82 (0.76 to 0.89)	−0.04 (−0.06 to −0.02)
Multiple gestation					
No	7542 (19.5)	31175 (80.5)	Referent	Referent	Referent

Continued

Table 1 Continued

Characteristic	Mode of delivery		RR (95% CI)		
	CS n=7640 (19.6%)	Vaginally n=31 386 (80.4%)	Unadjusted*	Adjusted†	Adjusted† AR (95% CI)
	N (row %)				
Yes	98 (31.7)	211 (68.3)	1.66 (1.36 to 2.02)	1.72 (1.41 to 2.10)	0.14 (0.07 to 0.21)
Gestational age at birth§					
Preterm	862 (15.5)	4706 (84.5)	0.77 (0.71 to 0.82)	0.80 (0.75 to 0.86)	−0.04 (−0.05 to −0.03)
Term	6720 (20.3)	26329 (79.7)	Referent	Referent	Referent

*Obtained from single variable Poisson regressions solved by GEE adjusting for clusters.
†Obtained from multivariable Poisson model solved by GEE adjusting for clusters. Model included time in years (categorical), maternal age, parity, education, BMI, anaemia status, multiple gestation and gestational age at birth. For the trend by years, a continuous term for years was included in the model instead of the categorical.
‡P values obtained from multivariable models were all < 0.001.
§ Overall missing was < 0.1 % to 0.9 %.
AR, absolute risk; BMI, body mass index; CS, caesarean section; GEE, generalised estimating equation; RR, relative risk.
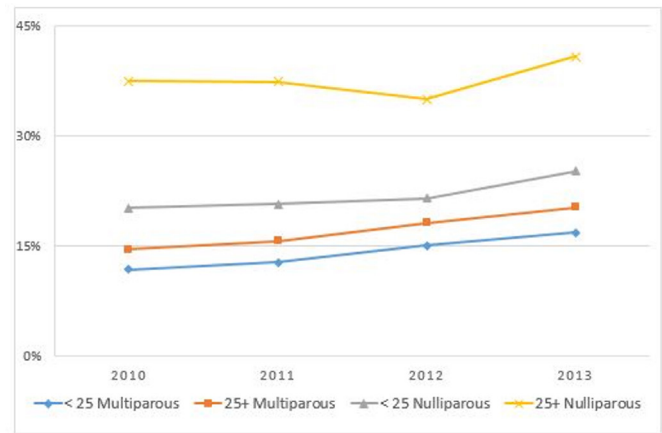

Figure 2 Trends in caesarean section rates 2010 to 2013 by parity and maternal age.

assessments of maternal and neonatal outcomes, which helped to develop the research question of this study.[13] The authors have been working in the study area for 10 years and provide regular feedback to the community regarding outcomes.

RESULTS

Figure 1 shows the flow diagram for the pregnant women enrolled in the MNHR between 1 January, 2010, and 31 December, 2013, and the women included in this secondary data analysis. Overall, the population-based registry included 41 691 pregnant women in the study catchment area, of which 39 026 (93%) were included in the secondary data analysis reported in this study. The reasons for exclusion of 6.4% of the women are shown in figure 1. Overall, 20% of the women delivered by CS. Only 1661 (5%) women delivered vaginally outside a facility.

The characteristics of women by mode of delivery and results from regression models are shown in the table 1. Results from adjusted regressions indicate that women aged 25+ years and nulliparous (RR (95% CI): 1.31 (1.18 to 1.44), AR (95% CI): 0.09 (0.06 to 0.12)), having a secondary (RR (95% CI): 1.38 (1.28 to 1.48), AR (95% CI): 0.05 (0.04 to 0.06)) or university education (RR (95% CI): 1.87 (1.73 to 2.03), AR (95% CI): 0.12 (0.11 to 0.14)0, having a BMI of 25+ (RR (95% CI): 1.57 (1.43 to 1.72), AR (95% CI): 0.12 (0.09 to 0.15)) and a multiple gestation pregnancy (RR (95% CI): 1.72 (1.41 to 2.10), AR (95% CI): 0.14 (0.07 to 0.21)) were more likely to deliver by CS.

CS rates increased annually from 17.4% in 2010, to 18.3% in 2011, to 19.9% in 2012 and to 22.7% in 2013 (p<0.001). Results from the adjusted regressions indicate that the relative risks (95% CI) increased by 1.08 (1.06 to 1.11) per year. As shown in figure 2, the rates varied by mother's age and parity with women aged 25+ and having their first child being more likely to have CS than younger women and multiparous women.

The single most likely reason for having a CS according to mother's age and parity is illustrated in figure 3.
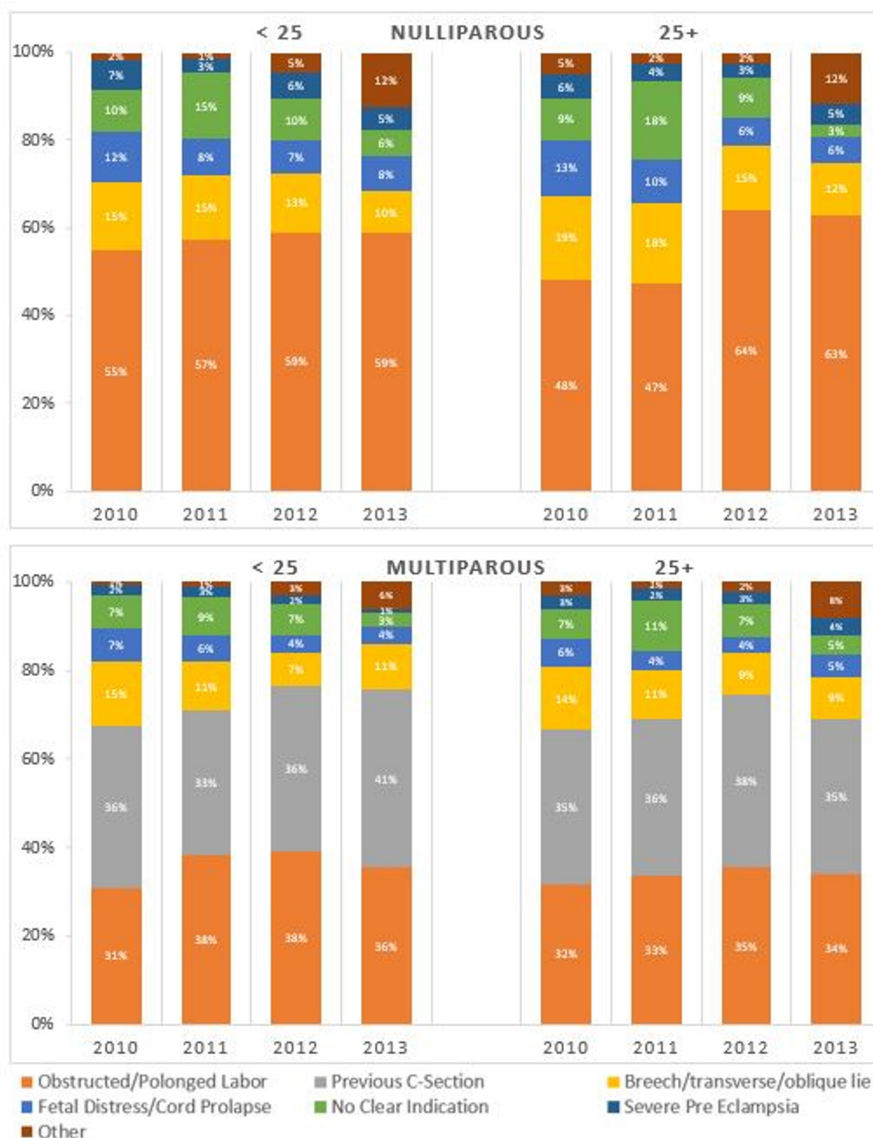
Figure 3 Trends in the most likely reason for caesarean section 2010 to 2013 by parity and maternal age.

Obstructed and prolonged labour is the most frequently reported reason increasing over time from 48% in 2010 to 63% in 2013 (p≤0.001) among the nulliparous women. Although the same reason is reported among the multiparous women, the rates are lower (31% to 38%). Prior CS was a common reason for CS in the multiparous women (36% to 37%).

A total of 15 women in this secondary data analysis died through day 42 post-partum for a maternal mortality rate of 38/100 000 total births. Four women delivering by CS died – two due to haemorrhage (stroke-1, haemorrhage unspecified-1), one due to pre-eclampsia/eclampsia and one due to an accident but no further details were available. All four women delivered neonates who were alive at day 29 of life. Eleven of the women delivering vaginally died – two due to sepsis, three due to suicide, one due to burns, two due to haemorrhage (stroke-1, haemorrhage unspecified-1), one due to jaundice, one due to pre-eclampsia/eclampsia and the cause was unknown for one

women. Of the 11 women who died, 4 of their babies were stillborn and seven were alive on day 29 of life.

Table 2 displays the association of CS and other characteristics with perinatal mortality. Perinatal mortality was higher among babies born vaginally than those delivered by CS (4.5% vs 2.7%, p<0.001) after adjusting for other covariates. Preterm deliveries are highly associated with perinatal mortality (RR (95% CI): 6.34 (5.64 to 7.12), p<0.001)) but our sample size is small to consider a multivariable analysis stratified by gestational age.

DISCUSSION

In this large rural population of pregnant women in central India who were followed prospectively to day 42 post-partum, the overall rate of CS was 20%, with a steady increase in rates between January 2010 and December 2013, similar to trends reported in other resource-poor countries.[14] The upward trend over time is likely related

Table 2 Unadjusted and adjusted results obtained from regressions assessing the relationship of CS and characteristics of pregnant women with perinatal mortality

| | Perinatal mortality | | Relative risks (95% CI) | | |
| | Yes
n=160 (4.1%) | No
n=37 417 (95.9%) | | | |
Characteristics	N (row %)		Unadjusted*	Adjusted†	P value‡
Caesarean section					<0.001
Yes	203 (2.7)	7437 (97.3)	0.61 (0.52 to 0.70)	0.65 (0.56 to 0.76)	
No	1406 (4.5)	29 980 (95.5)	Referent	Referent	
Time in years					0.02
2010	448 (4.5)	9619 (95.5)	Referent	Referent	
2011	344 (3.6)	9203 (96.4)	0.81 (0.70 to 0.93)	0.84 (0.73 to 0.97)	
2012	389 (4.1)	9118 (95.9)	0.92 (0.80 to 1.05)	1.00 (0.87 to 1.15)	
2103	428 (4.3)	9477 (95.7)	0.97 (0.85 to 1.11)	1.04 (0.91 to 1.18)	
Mother's age (years)					<0.01
<25	1083 (4.1)	25 562 (95.9)	Referent	Referent	
25+	526 (4.2)	11 855 (95.8)	1.05 (0.94 to 1.16)	1.20 (1.07 to 1.35)	
Parity					<0.001
Nulliparous	858 (4.6)	17 878 (95.4)	1.24 (1.13 to 1.37)	1.52 (1.36 to 1.70)	
Multiparous	751 (3.7)	19 539 (96.3)	Referent	Referent	
Mother's education*					<0.01
None/primary	393 (4.9)	7577 (95.1)	Referent	Referent	
Secondary	982 (4.2)	22 203 (95.8)	0.84 (0.75 to 0.94)	0.94 (0.84 to 1.06)	
University	233 (3.0)	7579 (97.0)	0.60 (0.51 to 0.70)	0.75 (0.63 to 0.88)	
BMI categories (kg/m*)§					0.09
<18.5	618 (4.6)	12 891 (95.4)	1.15 (1.04 to 1.28)	1.12 (1.01 to 1.24)	
18.5–24.9	933 (3.9)	23 106 (96.1)	Referent	Referent	
25.0+	57 (3.9)	1385 (96.1)	1.03 (0.79 to 1.35)	1.14 (0.87 to 1.49)	
Anaemia (haemoglobin g/dL)					0.03
None (≥11.0)	107 (3.2)	3275 (96.8)	Referent	Referent	
Mild (10.0–10.9)	626 (3.8)	15 659 (96.2)	1.22 (1.00 to 1.50)	1.15 (0.93 to 1.41)	
Moderate or severe (<10.0)	876 (4.5)	18 483 (95.5)	1.44 (1.17 to 1.76)	1.27 (1.03 to 1.56)	
Multiple gestation					<0.001
No	1544 (4.0)	37 173 (96.0)	Referent	Referent	
Yes	65 (21.0)	244 (79.0)	5.22 (4.07 to 6.71)	2.30 (1.79 to 2.96)	
Gestational age at birth§					<0.001
Preterm	844 (15.2)	4724 (84.8)	6.72 (5.98 to 7.56)	6.34 (5.64 to 7.12)	
Term	738 (2.2)	32 311 (97.8)	Referent	Referent	

*Obtained from single variable Poisson regressions solved by GEE adjusting for clusters.
†Obtained from multivariable Poisson model solved by GEE adjusting for clusters. Model Included CS, time in years, maternal age, parity, education, BMI, anaemia status, multiple gestation and gestational age at birth.
‡Obtained from multivariable models.
§Overall missing was <0.1% to 0.9%.
BMI, body mass index; CS, caesarean section; GEE, generalised estimating equation.

to activities conducted under the National Rural Health Mission and Janani Shishu Suraksha Yojana. These include health messages on television promoting mandatory hospital deliveries, quick referrals and efficient transport to upgraded referral hospitals. Other reasons include improved educational status of women residing in rural areas adjoining the city and higher BMI likely reflecting improved nutritional status and sedentary lifestyles.[15 16]

Characteristics associated with delivery by CS in our study were higher maternal age (25+), being nulliparous,

having a multiple gestation pregnancy, a higher maternal BMI (25+) and a maternal education of at least a secondary school. These results are similar to those reported by others,[7] particularly increased rates of CS that have consistently been reported in women with higher education, likely due to educated women having higher socioeconomic status and easier access to facilities where ultrasound and CS are available.[5 17] CS were less likely in women who were anaemic and those delivering prematurely. Maternal anaemia is a risk factor for preterm birth, low birth weight and intrauterine growth restriction, all of which result in higher rates of smaller, low birth weight babies that are easier to deliver vaginally.[18 19]

The most likely reason for CS included obstructed prolonged labour in both nulliparous and multiparous women. Due to increasing use of ultrasonography, there is improved identification of this indication during delivery resulting in higher rates of CS over time. In multiparous women, prior CS was frequently indicated as the most likely reason for the CS. Almost half the multiparous women reported a prior CS. Many providers in our catchment area are either uncomfortable with or unaware of the recent recommendations to promote vaginal birth after CS, when there are no other reasons for CS,[20 21] because of concerns about uterine rupture. CS remains indicated for prior obstetrical fistula repair,[22] obstructed labour due to increased risk of maternal and neonatal complications[23] and major antepartum haemorrhage.[24] Other indications include multiple pregnancy complications, because CS are considered safer than vaginal deliveries in this situation.[19] We could not study multiple complications because we only had information on the single most likely reason for CS. However, of particular concern in our study was the observation that 9.8% of nulliparous women and 6.5% of multiparous women had no clear indication for CS. A potentially interesting finding is the relationship between parity and maternal age with the most likely reason for CS, which if confirmed by others, may help to better understand this population to guide optimum delivery strategies.

We found that perinatal mortality was lower in women undergoing CS compared with vaginal delivery in our site. This was not surprising because rates of stillbirth and neonatal mortality were previously reported to be lower in women who underwent CS in the two Indian GN sites (Nagpur and Belgaum), although this trend was not observed in other GN sites.[6]

Strengths of our study include a large pregnancy and newborn population-based registry with prospective, standardised data collection in central rural India since 2009. However, we report data only on the full years of data collection from 2010 to 2013 while there was a single version of the data collection forms, simplifying comparison of study variables over time. Almost 95% of deliveries occurred in facilities that provided discharge summaries, likely improving accuracy of maternal and newborn outcomes compared with information from home deliveries. Enrolment of almost the entire population of pregnant women in the catchment area of 20 PHCs likely reduced selection bias. Limitations include lack of information on the type of delivery facility (private or government), not allowing comparison of our findings between private and public facilities. Recently published Indian National Family Health Survey data from 2015 to 2016[9] found CS rates to be significantly higher in private than government facilities. An important limitation of our study was the reporting of the single most likely reason for CS that was based on the discharge summary from the facility conducting the CS. This variable did not capture multiple complications, which may have been present. The single most likely reason was based on the clinician's assessment, as we did not train obstetricians conducting CS on reporting of indications for CS. The most likely reason reported may not be completely accurate due to the government mandate to conduct CS only in specific circumstances leading to an over-reporting of certain conditions necessitating CS. Our database also lacked information on whether the CS was elective or an emergency CS, although repeat CS to avoid vaginal delivery would likely be elective, where many other conditions would likely be life-threatening. Finally, we could not evaluate the role of the woman's socioeconomic status on CS rates, as the only proxy for this in our database was years of maternal education.

CONCLUSION

In this study, we found high rates of institutional deliveries and increasing rates of CS in the rural eastern Maharashtra between 2010 and 2013. Although we did not find any new characteristics of the pregnant women associated with CS, we found an interaction between parity and maternal age: the highest rates of CS were in nulliparous women aged 25 and over. Trends over this period in the single most likely reason for CS showed that obstructed and prolonged labour increased over time for nulliparous and multiparous women. Prior CS was a common reason for CS in multiparous women. Between 6% and 10% of deliveries did not have a clear indication for CS. What leads to CS when there is no clear indication needs further investigation before advocating policy changes to reduce unnecessary CS.

Patient consent for publication Not required.

Ethics approval The MNHR at Nagpur, India, was reviewed and approved by the ethicalreview boards of the Lata Medical Research Foundation Institutional ReviewBoard (FWA00012971), the Partners Human Research Committee (FWA00003136) andBoston University Medical Campus IRB (FWA00000301) in Boston, Massachusetts, USA.

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Data sharing statement A de-identified minimal data set that underlies the findings and conclusions described in the manuscript can be shared upon request by the editors to verify the reported study findings.

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