



# Adverse infant outcomes associated with caesarean section delivery in India

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**Background:** Caesarean section delivery is increasing worldwide and in India, yet little is known about the effect on infants. We examined the association between caesarean delivery and adverse infant outcomes in an Indian national survey, accounting for factors related to the mode of delivery.

**Methods:** Inverse probability weighted logistic regression analysis of the 2015–2016 India National Family Health Survey obtained adjusted ORs (aORs) and 95% CIs. Infant outcomes were maternal report of recent concomitant diarrhoea and acute respiratory infection (ARI) in infants age  $\leq 6$  mo and neonatal death.

**Results:** Of the 189 143 reported most recent singleton births, 15.4% were delivered by caesarean, 860 (3.2%) of all infants age  $\leq 6$  mo had concomitant diarrhoea and ARI and 3480 (1.8%) neonatal deaths were reported. In adjusted analysis, caesarean delivery was not associated with concomitant diarrhoea and ARI (aOR 0.96 [95% CI 0.71 to 1.32]) but was associated with neonatal death (aOR 1.19 [95% CI 1.02 to 1.39]).

**Conclusions:** Using nationally representative cross-sectional data for India, caesarean section delivery was found to be associated with neonatal death after accounting for factors associated with the mode of delivery. Prospective exploration of the relationship between caesarean delivery and adverse infant outcomes is warranted.

**Keywords:** cesarean section, India, infant health, neonatal death

## Introduction

Caesarean section delivery has been found to be associated with adverse infant outcomes, including impaired gastrointestinal and respiratory health, and mortality.<sup>1,2</sup> In many countries, place of residence (urban or rural) can determine the quality of maternal care that is available and accessed, and can also affect infant outcomes. Furthermore, numerous other factors are associated with the mode of delivery, including receipt of antenatal care, maternal characteristics and societal norms.<sup>3</sup>

Caesarean delivery rates have been rapidly increasing worldwide.<sup>4,5</sup> Currently it is estimated that more than one in five births globally are delivered by cesarean.<sup>5</sup> An analysis of national

data from 159 countries found that neonatal and maternal mortality rates were lowest among countries with national caesarean delivery rates between 5% and 10%.<sup>6</sup> However, the mortality rates appeared to plateau with caesarean delivery rates  $>10\%$ .<sup>6</sup> This implies that there are no additional benefits of high caesarean delivery rates in addressing mortality. Moreover, the WHO recommends that the caesarean delivery rate should not exceed 15% of births in all regions.<sup>4</sup>

Caesarean delivery rates are also increasing nationally in India. The 2015–2016 India National Family Health Survey (NFHS-4) estimates that 17.2% of all births nationwide are delivered by caesarean.<sup>7</sup> The estimated rates by rural and urban residence are 12.9% and 28.3%, respectively. However, it is unknown how

socio economic, healthcare and maternal factors collectively contribute to the caesarean delivery rate in India, which in turn could impact infant outcomes. The purpose of this study is to determine whether caesarean delivery is associated with adverse infant outcomes in a nationally representative survey, controlling for key socioeconomic, healthcare and maternal factors identified to be associated with caesarean delivery.

## Materials and methods

### Study population and sampling

We obtained data from the NFHS-4, a nationally representative cross-sectional household survey conducted by the International Institute for Population Sciences and the Demographic and Health Survey (DHS) programme.<sup>8</sup> The main purpose of the NFHS is to provide reproductive, maternal and child health information for India.<sup>9</sup> Data were requested from and provided via the DHS programme.

The survey sample for the NFHS-4 was obtained by two-stage stratified sampling, using the 2011 national census as the sampling frame.<sup>8</sup> The NFHS-4 was designed to provide information at the national, state and district levels and by urban or rural residence. Questionnaires were conducted between January 2015 and December 2016. Ever-married women aged 15–49 y were interviewed with the ‘Woman’s Questionnaire’ on a range of topics including prenatal experience and their child’s health.

Our analysis included the most recent singleton births, up to 5 y prior to the survey, for whom information on antenatal care and prenatal health was collected. In total, 699 686 women aged 15–49 y were surveyed in the NFHS-4. After excluding multiple births and women whose most recent births were not within the prior 5 y, the final sample included responses from 189 143 women.

### Key measures

Mode of delivery was determined by self-report to the interview question ‘Was (child’s name) delivered by caesarean section?’

We assessed two infant outcomes. First, recent severe illness was determined by maternal report of whether the infant had concomitant diarrhoea and symptoms of acute respiratory illness (ARI; cough accompanied by short, rapid breathing) in the 2 wk before the interview in infants  $\leq 6$  mo of age. Second, neonatal death was determined by maternal report of the child’s age at death. Of the 5459 reported child deaths, 3480 (63.75%) were in the first month of life.

### Predictor variables

Socio-economic, healthcare and maternal factors associated with caesarean delivery were identified for propensity score analysis. Demographic variables included place of residence (urban or rural), religion, caste, wealth index (a DHS created composite variable measuring household wealth), maternal age, education, marital status, employment status and partner’s occupation. Antenatal care (ANC) variables included number of ANC visits, timing of ANC and whether ANC was received at a government facility or private hospital. Reproductive history

variables included parity, and whether the mother had ever terminated a pregnancy. Few prenatal health conditions are assessed in the survey. Prenatal variables available in the dataset included maternal iron supplementation, day vision difficulties, use of intestinal parasitic medication, convulsions during pregnancy and body swelling. Delivery variables included in the NFHS-4 were whether delivery occurred in a public or private facility (for caesarean deliveries), experience of breech presentation, prolonged labour or excessive bleeding, in addition to the timing of the caesarean in relation to the onset of labour (before or after labour) in women who delivered by caesarean.

Infant covariates included infant sex, year of birth and reported birthweight. Breastfeeding status was assessed as whether they were ever breastfed, timing of breastfeeding initiation and whether a living infant was currently breastfeeding. Infant’s gestational age at birth was not assessed in the NFHS-4. All predictor variables were determined by maternal self-report.

### Statistical analysis

A multivariable logistic regression model of demographic, antenatal and delivery factors was used to create propensity scores for mode of delivery, incorporating the survey sampling weight.<sup>10</sup> Propensity scores aim to balance the baseline factors associated with the exposure—mode of delivery—by each exposure group (caesarean vs vaginal delivery), mimicking randomization of baseline factors and reducing bias for known confounders in the relationship between mode of delivery and infant outcomes. Propensity score balance was assessed by common support and standardized difference.

The crude relationship between mode of delivery and infant outcome was assessed by logistic regression, obtaining ORs and 95% CIs. The product of the survey sampling weight and the inverse of the propensity score was applied as a weight to the logistic regression models to obtain adjusted ORs (aORs) for the relationship between mode of delivery and diarrhoea and concomitant ARI in infants  $\leq 6$  mo of age, and with neonatal death in a separate model.

Sensitivity analysis for neonatal death was conducted in infants whose mothers recalled or had a health card indicating the infant’s birthweight as  $>2500$  g in order to assess the association between neonatal death and mode of delivery in normal weight infants.

All analyses were conducted using SAS 9.4 (SAS Institute, Cary, NC, USA) and Stata 12 (StataCorp, College Station, TX, USA).

## Results

Of the 189 143 most recent singleton births reported in the NFHS-4, 29 208 (15.4%) were delivered by caesarean. Of the children who were still alive, 26 560 were  $\leq 6$  mo of age, and 860 (3.2%) of those had reports of the severe outcome of concomitant ARI and diarrhoea in the previous 2 wk.

Factors positively associated with caesarean delivery that were included in the propensity score multivariable model predicting mode of delivery included place of residence, wealth index, maternal education level, number of ANC visits, timing of

**Table 1.** Characteristics of infants  $\leq 6$  mo of age with and without concomitant diarrhoea and ARI in the 2015–2016 India National Family Health Survey

Characteristics	Infant not severely ill (n=25 690), %	Infant severely ill with concomitant ARI and diarrhoea (n=860), %	p-Value <sup>a</sup>
Mode of delivery			0.1004
Vaginal	80.8	84.2	
Caesarean	19.2	15.8	
Birthweight (g), mean (SE)	2810.20 (5.65)	2856.84 (34.31)	0.1852
Infant sex			0.8771
Male	52.3	52.6	
Female	47.7	47.4	
Year of birth			<0.0001
2014	23.6	35.4	
2015	55.3	55.3	
2016	21.2	15.7	
Age at interview (mo), mean (SE)	3.37 (0.02)	4.28 (0.07)	<0.0001
Breastfeeding			
Ever breastfed	97.9	98.0	0.7627
Initiated breastfeeding immediately	43.0	30.4	<0.0001
Initiation of breastfeeding within 1 h	67.8	55.2	<0.0001
Currently breastfeeding	95.5	94.4	0.3542

<sup>a</sup>Determined by Wald's  $\chi^2$  after applying national survey weights.

Missing data: mode of delivery, n=10; infant sex, n=10; year of birth, n=10; post-natal appointment, n=60; ever breastfed, n=20; initiated breastfeeding immediately or within 1 h, n=624; currently breastfeeding, n=10.

the first ANC visit, place where the ANC occurred and place of delivery (Supplemental Table 1).

For infant health outcomes, a smaller proportion of infants  $\leq 6$  mo of age with concomitant diarrhoea and ARI in the previous 2 wk were delivered by caesarean (15.8%) compared with those who were not severely ill (19.2%,  $p=0.1004$ ) (Table 1). Moreover, a higher proportion of the infants who were not severely ill were reported to have initiated breastfeeding immediately after birth or within the first hour.

In both the crude and adjusted analysis, no association was found between caesarean delivery and report of severe infant illness (OR 0.79 [95% CI 0.58 to 1.07] and aOR 0.96 [95% CI 0.71 to 1.32], respectively; Table 2). Neither was there an association between the mode of delivery and report of diarrhoea or ARI individually (data not shown).

Of the infants that died in the first month of life, fewer were delivered by caesarean (15%) compared with those who were still alive at the time of the survey (19%; Table 3). Further, a greater proportion of infants who died were born in 2014 or 2015, and a smaller proportion were reported to have ever been breastfed compared with those still alive.

In the unadjusted model, caesarean delivery was associated with a decreased likelihood for neonatal death (OR 0.77 [95% CI 0.68 to 0.87]; Table 4). After adjusting for the inverse of the

**Table 2.** Crude and adjusted association between mode of delivery and concomitant diarrhoea and ARI among infants  $\leq 6$  mo of age in the 2015–2016 India National Family Health Survey

Mode of delivery	Unadjusted OR (95% CI)	aOR <sup>a</sup> (95% CI)
Caesarean vs vaginal	0.79 (0.58 to 1.07)	0.96 (0.71 to 1.32)

<sup>a</sup>Model adjusted for inverse probability weighting predicting mode of delivery with place of residence type, wealth index, highest education level, number of ANC visits, timing of first antenatal appointment, ANC received at government/municipal hospital or private/maternity hospital and place of delivery.

propensity score as a weight in the logistic regression model, caesarean delivery was positively associated with neonatal mortality (aOR 1.19 [95% CI 1.02 to 1.39]). This positive association remained after further adjusting for reported delivery complications (aOR 1.22 [95% CI 1.04 to 1.44]).

**Table 3.** Infant characteristics in the 2015–2016 India National Family Health Survey by vital status

Characteristics	Child alive at interview (n=185 663), %	Neonate died in first month (n=3480), %	p-Value <sup>a</sup>
Mode of delivery			
Vaginal	80.8	84.6	
Caesarean	19.2	15.4	<0.0001
Birthweight (g), mean (SE)	2817.38 (2.22)	2608.92 (25.29)	<0.0001
Infant sex			
Male	54.4	56.4	
Female	45.6	43.6	0.0634
Year of birth			
2010	5.9	2.4	
2011	12.3	7.0	
2012	16.8	10.5	<0.0001
2013	21.6	17.4	
2014	25.9	30.1	
2015	15.3	27.0	
2016	3.0	5.6	
Breastfeeding			
Ever breastfed	95.7	36.0	<0.0001
Initiated breastfeeding immediately	43.9	39.3	0.0112
Initiation of breastfeeding within 1 h	69.2	68.3	0.6010

<sup>a</sup>Determined by Wald's  $\chi^2$  after applying national survey weights.

Missing data: ever breastfed, n=484; initiated breastfeeding, n=10 777; missing birthweight, n=42 795.

**Table 4.** Crude and adjusted association between mode of delivery and neonatal death in the 2015–2016 India National Family Health Survey

Mode of delivery	Unadjusted OR (95% CI)	aOR <sup>a</sup> (95% CI)	aOR <sup>b</sup> (95% CI)
Caesarean vs vaginal	0.77 (0.68 to 0.87)	1.19 (1.02 to 1.39)	1.22 (1.04 to 1.44)

<sup>a</sup>Model adjusted for inverse probability weighting predicting mode of delivery with place of residence type, head of household caste, wealth index, highest education level, number of ANC visits, timing of first antenatal appointment, ANC received at government/municipal hospital or at private/maternity hospital, place of delivery, parity and prenatal iron supplementation.

<sup>b</sup>Adjusted for propensity score weight and delivery complications: prolonged labour, excessive bleeding and breech position.

Of all 189 143 deliveries, 146 348 (77%) reported a birthweight and 122 208 of these had a reported weight >2500 g, 1186 (0.97%) of which were neonatal deaths. In sensitivity analyses, there was no relationship between caesarean delivery and neonatal mortality in infants who were reported to weigh >2500 g at birth (OR 1.03 [95% CI 0.85 to 1.23]), although a positive relationship was found in the weighted model (aOR 1.43 [95% CI 1.15 to 1.78]).

## Discussion

In our analysis of nationally representative data for India, we identified socioeconomic and healthcare factors associated with an increased likelihood for caesarean delivery. After controlling for these factors using propensity score analysis, we found that

caesarean delivery was not associated with maternal reports of concomitant diarrhoea and ARI among infants  $\leq 6$  mo of age, but there was a positive association with neonatal death.

We found no association between caesarean delivery and a measure of severe illness among infants  $\leq 6$  mo of age, even after adjusting for confounding socioeconomic and healthcare variables. This is consistent with findings from other studies conducted in low- and middle-income countries, including India.<sup>11–13</sup> Rather than mode of delivery, factors such as family health history and the child's environment were found to affect adverse infant health outcomes.<sup>11,13</sup> In contrast, studies in Western countries tend to find an increased risk of adverse health outcomes in children delivered by caesarean.<sup>1,14</sup> This relates to the theory that infants delivered by caesarean are exposed to different bacteria at birth compared with infants delivered vaginally and thus may have a propensity towards immune-related conditions

throughout their lives.<sup>15</sup> Our findings suggest that in India, on a population level, mode of delivery is not the most important predictor for the outcomes of recent gastrointestinal and respiratory adverse health in infants.

With 3480 neonatal deaths, the neonatal mortality rate in our study sample of most recent births between 2010 and 2016 was 18 neonatal deaths per 1000 live births, which is similar to the 2015 global rate of 19 neonatal deaths per 1000 live births, but lower than the national 2015 estimate for India of 28 neonatal deaths per 1000 live births.<sup>16</sup> We found an association between caesarean delivery and neonatal mortality, after adjusting for socioeconomic and healthcare confounders using inverse probability of treatment weighting. This finding is consistent with a previous study of nationally representative data from 46 low- and middle-income countries. They found that neonatal mortality was highest in countries with low (<5%) and medium (5–15%) national rates of caesarean delivery, but no association with neonatal mortality was found in countries with caesarean rates >15%.<sup>2</sup> Another study of data from 126 countries found that caesarean delivery was positively associated with maternal, infant and neonatal mortality in countries with caesarean delivery rates >15%.<sup>17</sup> Similar to our study, they accounted for socioeconomic variables in their analyses, which indicates the important role of macrolevel factors on caesarean delivery, and possibly access to and use of healthcare in general, and neonatal mortality. However, not all multinational studies have found a positive association between caesarean delivery and neonatal mortality. Two studies that each included data from >100 countries found an inverse association between caesarean rates and neonatal mortality rates.<sup>18,19</sup> These conflicting findings point to the complexity in studying associations at the population level with cross-sectional data, and further investigation into the maternal health factors associated with neonatal mortality is needed using prospective studies.

The strengths of our study include using a large, nationally representative dataset, which provided enough statistical power to assess neonatal mortality, a rare outcome. To determine the adjusted impact of caesarean delivery on infant outcomes, we used propensity score analysis to balance exposure groups, which has not previously been conducted with Indian national data. Furthermore, some previous studies examining the relationship between mode of delivery and adverse infant outcomes did not control for socioeconomic factors. Thus their findings were likely confounded as socioeconomic status can affect both mode of delivery and infant outcomes, as shown in our study.

A key limitation of this study is that we analysed cross-sectional survey data and thus cannot infer causality of the observed associations. Another limitation is that we were unable to determine the indication for caesarean delivery, which was also obtained by self-reports. However, we were able to account for maternal reports of delivery complications in our analysis of infant outcomes. For adverse infant health outcomes, we were limited to assessing ARI and diarrhoea within the past 2 wk. In addition, we did not have a measure for gestational age at birth, which is an important predictor of adverse infant outcomes. However, we were able to analyse a subset of infants with recorded or recalled birthweight and exclude infants weighing <2500 g, as a proxy for excluding infants who were likely born

preterm or with medical conditions. We acknowledge that there may still be residual confounding by variables not measured in the survey. Furthermore, all of our key measures, the exposure and the outcomes were determined by self-reports, which could lead to over- or underreporting and bias our estimates. As some women may have had their most recent birth up to 5 y prior to the survey, recall bias may have affected responses pertaining to ANC and delivery. However, the interview process is standardized with trained interviewers to decrease respondent bias, and studies have shown that retrospective maternal reports in the DHS are reliable, including reports of caesarean delivery.<sup>20</sup> Lastly, the survey could only be conducted among living women, thus information pertaining to the birth outcomes of mothers who had pregnancy-related deaths were not captured.

## Conclusions

This study suggests that after accounting for socioeconomic and healthcare factors associated with mode of delivery in India, there is an association between caesarean delivery and neonatal death. In light of the increasing caesarean delivery rate in India, interventions should be considered to prevent adverse outcomes, particularly neonatal mortality. Future studies should assess the relationship between mode of delivery and adverse infant outcomes prospectively, also accounting for individual-level factors and the role of the healthcare facility.

**Authors' contributions:** TG, CHB, GT, HS and CLH developed the study research question. TG and GT planned the statistical analyses conducted by TG. KB, GNK, CHB and CLH revised the manuscript for details on country-specific content. All authors contributed to data interpretation and revisions of the initial manuscript drafted by TG and CLH and reviewed the final manuscript.

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