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Health insurance coverage, neonatal mortality and caesarean section deliveries: an analysis of vital registration data in Colombia

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ABSTRACT

Background

Low- and middle-income countries have introduced different health insurance schemes over the last decades, but whether different schemes are associated with different neonatal outcomes is yet unknown. We examined the association between health insurance coverage scheme and neonatal mortality in Colombia.

Methods

We used Colombian national vital registration data, including all live births (2,506,920) and neonatal deaths (17,712) between 2008-2011. We used Poisson regression models to examine the association between health insurance coverage and the neonatal mortality rate (NMR), distinguishing women insured via the contributory scheme (40% of births, financed through payroll and employer's contributions), Government subsidized insurance (47%), and the uninsured (11%).

Results

The NMR was lower among babies born to mothers in the contributory scheme (6.13/1000) than in the subsidized scheme (7.69/1000) or the uninsured (8.38/1000). Controlling for socioeconomic and demographic factors NMRs remained higher for those in the subsidized scheme (OR 1.09, 95%CI 1.05-1.14) and the uninsured (OR 1.16, 95%CI 1.10-1.23) compared to those in the contributory scheme. These differences increased in models that additionally controlled for C-section delivery. This increase was due to the higher fraction of C-section deliveries among women in the contributory scheme (49%, compared to 34% for the subsidized scheme and 28% for the uninsured).

Conclusion

Health insurance through the contributory system is associated with lower neonatal mortality than insurance through the subsidized system or lack of insurance. Universal health insurance may not be sufficient to close the gap in newborn mortality between socioeconomic groups.

What is already known on this subject

Health insurance coverage lowers the risk of catastrophic health expenditures and improves access to healthcare, but there is a paucity of evidence on associations with newborn health and mortality.

What this study adds

Based on analyses of all live births (2,506,920) and neonatal deaths (17,712) in the Colombian national vital registration system between 2008-2011, we find that health insurance coverage is associated with a small reduction in neonatal mortality. Results suggest that unnecessary C-sections among women with contributory insurance may offset some of the positive effects of improved access to care.

Policy Implications:

- Statutory free maternity care may contribute to better newborn survival, although it may not be sufficient to close the gap in newborn mortality between socioeconomic groups.
- Beyond increasing health insurance coverage, policies to decrease differences in access to and quality of care between insurance status groups may be required to reduce infant mortality.

Introduction

Expansion of health insurance coverage has become a priority for many governments.[1-6] Universal health coverage - ensuring that all people receive the health services they require, of good quality, without exposing the user to financial hardship when paying for them - is a key component of the Sustainable Development Goals.[7] In low and middle income countries, use of maternity care is sensitive to out-of-pocket fees,[8] as the costs of care can be unpredictable[9] and can amount to a substantial proportion of household income, especially for caesarean section (C-section) deliveries.[8] Health insurance coverage lowers the risk of catastrophic health expenditures and improves access to healthcare, but there is a paucity of evidence on its effects on health outcomes, including newborn mortality.[10-12] While expansion of health insurance coverage has become a priority of governments, whether improvements in newborn survival can be achieved by expanding health insurance coverage remains uncertain.

Colombia offers a unique setting to examine the relationship between health insurance coverage and newborn mortality. Through a major reform in 1993, universal health insurance was gradually introduced to provide all citizens with a comprehensive health benefit package. A decentralization reform in early 2000[13] is believed to have improved efficiency and equity of resource allocation,[14] contributing to a substantial increase in insurance coverage (Figure 1). Individuals participate in one of two health insurance schemes: (i) Employees in the formal sector are mandated to enroll in an employment-based health insurance denominated 'Contributory Regime'. Even individuals with poverty scores below the eligibility threshold are mandated to enroll in this scheme; (ii) the Subsidized Regime, a publicly-funded health insurance scheme targeted to the poor as identified through a proxy means-test denominated System of Identification of Beneficiaries (SISBEN). Individuals in this scheme are subsidized to purchase insurance from private, government-regulated insurers.[15, 16] In theory, everyone, irrespective of insurance status, has access to free maternity care, also uninsured women. In practice, there are differences in quality of care between schemes and between the insured and uninsured, and additional financial barriers may limit access to care among the uninsured.[17, 18]

We use vital registration data to examine the association between health insurance coverage scheme and neonatal mortality in Colombia. We focus on neonatal mortality because it is sensitive

to quality of care.[19, 20] We expected health insurance, particularly via the contributory scheme, to be associated with better maternity and neonatal care, including access to emergency obstetric care.

Methods

Data

Vital registration data comprising individual records of all registered births and deaths between 2008 (when the vital registration bases in Colombia were harmonized) and 2011 were obtained from the National Administrative Department of Statistics' official registries.[21] For all deaths under 28 days (n=22,879) and all live births (n=2,734,478), information was recorded on characteristics of the child (year of birth, region of birth, sex, gestational age, birth weight), the mother (insurance status, age, marital status, rural/urban residence), and the delivery (singleton/multiple birth, mode of delivery (C-section, vaginal)). Cause-of-death data were coded according to the International Classification of Diseases (ICD-10) (Table S1).[22]

We found 8.3% of births and 38.7% of deaths had a missing value for at least one covariate. To minimize bias due to missing observations, we used multiple imputation methods developed by Raghunathan and colleagues[23] to impute values for education, marital status, and maternal age in deaths records. This method consists of fitting a sequence of regression models and drawing values from the corresponding predictive distributions, using observed values. The procedure was applied based on a model that included urban/rural residence, county of residence, sex of the baby, age of the baby at neonatal death, and year of death as covariates. We obtained five imputed databases based on five iterations. We excluded 3,701 death records (16%) for which at least one missing variable could not be imputed, yielding a sample of 19,178 neonatal deaths (83.8%).

Personal identifiers were not available for birth and death records. Therefore, we first aggregated the databases to obtain counts of live births and neonatal deaths according to health insurance status (contributory scheme, subsidized scheme, other schemes, uninsured), infant's sex, year of birth, region of residence, mother's age (≤ 19 , 20-34, 35 years+), maternal education (lower secondary or less, upper secondary or higher), marital status (married, non-married), rural/urban residence, singleton/multiple birth, mode of delivery (vaginal delivery, C-section delivery), gestational age at birth (< 37 weeks, 37 weeks or more), and birthweight (< 2500 grams, 2500 grams or more). We then matched the birth and death databases based on aggregation variables to obtain a single merged database with both neonatal deaths (numerators for the rate) and live births (denominators for the rate). We found that 1,466 deaths (7.7%) could not be linked to the birth dataset, and were therefore excluded. The final dataset for analysis comprised 2,506,920 (91.7% of total) live births and 17,712 deaths (77.4%). Birth weight and gestational age came from different sources in the database of births (source: birth certificates) and the database of deaths (source: relatives' self-reports). To reduce risk of missclassification, we aggregated these variables using the broad categories mentioned above. Detailed categories for these variables as given in Table 1 were only retained when analyzing the birth database.

Finally, 2.5% of births were to mothers with another type of health insurance – a heterogeneous group that comprised a high percentage of mismatched deaths (33.5%) (results not shown). This group was therefore excluded from the presentation of findings.

Analysis

First, we estimated crude neonatal mortality rates (NMR), defined as the number of deaths under 28 days of life per 1,000 live births (Panel 1), the definition used by the Colombian authorities. This definition differs slightly from the more common definition that includes the 28th day of life, but this should not bias our estimates as the definition was applied uniformly across all regions and time periods. To explore the association between neonatal mortality and health insurance, we used Poisson regression models that included the number of deaths as dependent variable, the natural log of birth counts as offset variable, and health insurance as independent variable. In some models, we also explored the association between mode of delivery and health insurance using logistic regression.

We used a step-wise approach to modeling the association between health insurance and neonatal mortality on the basis of our conceptualized causal framework (Figure S1). Our basic model (Table 2, Model 1) included health insurance status and elementary confounders (year of birth, region of birth, sex of the infant, single/multiple birth, maternal age). To examine the extent to which mortality disparities by health insurance status were explained by socioeconomic and demographic factors, we incorporated adjustment for maternal education, marital status and rural/urban residence (Model 2). Then, we included mode of delivery (vaginal/C-section) as potential mediator of the association between health insurance status and neonatal mortality (Model 3). In Model 4, we included birth weight and gestational age as additional potential mediators. We also carried out separate analyses by cause-of-death.

Regression analyses were conducted using each of the five multiple databases generated by the multiple imputation process, using standard techniques in the PROC MIANALYZE procedure in SAS to combine estimates from all databases and adjust standard errors to account for uncertainty in the imputation.[24] This procedure reads the parameter estimates and associated covariance matrix for each imputed data set, and then derives valid multivariate inferences for these parameters. This allows for valid statistical inference that appropriately reflects uncertainty due to missing values.[24]

All analyses were conducted in SAS[®] version 9.2.

Results

47% of births were to mothers with subsidized insurance, 40% to mothers in the contributory scheme, and 11% to uninsured mothers (Table 1).

Teenage motherhood, lower education, rural residence and being unmarried were more common among uninsured mothers and those with a subsidized insurance, while being a mother aged 35 years and older was more common in the contributory scheme. The fraction of babies delivered through C-section was higher among mothers insured in the contributory scheme (49%), than among mothers in the subsidized scheme (34%) or uninsured mothers (28%). We found 46% of babies born to mothers in the contributory scheme were born before 39 weeks of gestational age,

versus 38% in the subsidized scheme and 40% born to uninsured mothers. The prevalence of low birth weight (<2500g) was roughly similar across babies born to mothers with different insurance status (contributory scheme 10%, subsidized scheme 8%, uninsured 9%).

The crude NMR was lower among babies born to mothers in the contributory scheme (6.13/1000) than among babies born to mothers in the subsidized scheme (7.69/1000) and uninsured mothers (8.38/1000) (Panel 1). While these differences were observed for all age-at-death groups, over three-quarters of the absolute difference occurred in the early neonatal period (first week), in particular in the first 24 hours after birth (50%). For most causes of death, except for congenital and chromosomal abnormalities, the crude NMR was higher for babies born to uninsured mothers and to women with a subsidized insurance. Deaths due to respiratory disorders, mostly respiratory distress related to conditions around delivery, contributed most to the absolute mortality difference by insurance status.

Results from the basic model suggest that, compared with the contributory insurance, the NMR was 27% higher (95%CI 1.22-1.31) among those born to mothers in the subsidized scheme, and 36% higher (95%CI 1.30-1.43) among babies born to uninsured mothers (Table 2, Model 1). These differences were partly explained by socioeconomic and demographic factors, but statistically significant differences remained after socioeconomic adjustment (rate ratio [RR] uninsured, 1.16 [95%CI 1.10-1.23]; RR subsidized scheme, 1.09 [95%CI 1.05-1.14]) (Table 2, Model 2). When examining cause-specific mortality, we noted a strong association between health insurance status and mortality from respiratory disorders (RR_{subsidized vs. contributory scheme} Model 2: 1.22 [95%CI 1.14-1.31]; RR_{uninsured vs. contributory scheme} Model 2: 1.37 [95%CI 1.25-1.50]) (Table S2).

Adjusting for delivery mode increased the mortality disadvantage of babies born to uninsured mothers and those with a subsidized insurance compared to those in the contributory scheme (RR uninsured, 1.27 [95%CI 1.20-1.35]; RR subsidized scheme, 1.17 [95%CI: 1.12-1.22]) (Table 2, Model 3). Further adjustment for gestational age and birth weight attenuated the increased mortality risk for the uninsured, but not for those in the subsidized scheme (Table 2, Model 4).

We further examined the role of C-section delivery. Table 2 (Model 3) shows that the NMR was 75% (95%CI 1.69-1.80) higher among C-section births than among vaginal births, after adjusting for sex, year, region, maternal age, education, rural/urban residence, and insurance status. The higher mortality among C-section births was substantially attenuated after controlling for gestational age and birth weight (ARR 1.05 [95%CI 1.02-1.09]) (Table 2, Model 4). Results in Table 3 show that being born before 39 weeks of gestational age and having low birth weight were more common for C-section deliveries than vaginal deliveries, irrespective of insurance scheme. We found that 50.7% of C-section births occurred before 39 weeks, versus 35.5% of vaginal births (<37 weeks: 12.9% and 6.5% respectively). Differences in birth weight and gestational age were small between insurance schemes when controlling for delivery mode. Finally, Figure 2 shows that the odds of C-section delivery were much lower for uninsured mothers (OR: 0.61 [95%CI 0.60-0.62]) and mothers in the subsidized scheme (OR 0.76 [95%CI 0.75-0.77]) than for women with a contributory insurance (see also Table S4).

Discussion

Summary of main findings

Our study shows that neonatal mortality was higher among babies from uninsured mothers and those with a subsidized insurance, compared to babies from mothers with a contributory insurance. After adjusting for socioeconomic and demographic factors, these mortality differences were attenuated but not eliminated. While possibly due to residual confounding, the remaining mortality disparities may also reflect differences in access to and quality of care. This hypothesis is supported by our finding that a substantial proportion of the mortality difference was attributable to deaths in the first 24 hours and to respiratory distress during delivery. Interestingly, mortality differences by insurance status became larger after adjusting for C-section delivery. This was due to the higher C-section rates among insured mothers, especially those in the contributory scheme -a practice that was associated with premature birth and higher neonatal mortality. *Further studies are warranted to establish whether a contributory health insurance may be associated with higher rates of unindicated C-sections, and whether the latter may have increased neonatal mortality for babies in the contributory scheme.*

Strengths and limitations

Missing values, mismatching, and under-registration of deaths may have led to an underestimation of average NMR and differences in NMR by insurance status. While under-registration of deaths is a problem in many low- and middle-income countries,[25] it has strongly declined in Colombia and vital registration coverage was high in the years we included.[26] Under-registration of deaths was largest in deprived areas with more uninsured people and those with a subsidized insurance, and may have led to an underestimation of mortality disparities.[27, 28] Mismatching and missing values may have also contributed to underestimated mortality differences, particularly between the uninsured and the insured.

We conducted three sensitivity analyses to evaluate the effect of mismatching and missing values. First, to limit the problem of mismatching and missing values in the covariates, we constructed a dataset with insurance status, year, and sex only, as using only these three variables –as opposed to all variables available- reduced the probability of mismatching considerably (only 3.4% of deaths were excluded due to missing values using these three variables). The rate ratios for the uninsured became higher than those in Table 2, Model 1 (RR uninsured: 1.62 [95%CI 1.55-1.68]); RR subsidized scheme: 1.28 [95%CI 1.25-1.32]), suggesting that the mortality differences between the uninsured and contributory scheme were underestimated. Second, to evaluate the effect of missing values for health insurance status, we estimated (i) a conservative model in which all deaths with missing values for insurance status were attributed to the contributory scheme and all births with such missing values to the uninsured, yielding a RR of 1.33 (95%CI 1.28-1.39); (ii) a model that attributed all deaths with a missing value for insurance status to the uninsured group, and births with missing values for insurance status to the contributory scheme, yielding a RR of 2.07 (95%CI 1.99-2.15). As the uninsured were more likely to have missing values for insurance status, the latter may provide a closer approximation of the actual mortality differences. Finally, we re-ran the models in Table 2 for the five largest regions with much higher quality of vital registration (Antioquia, Bogota, Cundinamarca, Valle, Atlántico), comprising 46% of all deaths (Table S3). Here, only 7% of deaths were dropped due to missing values or mismatching. The mortality differences between the uninsured and contributory schemes were slightly higher than

those in Table 2. Overall, these findings suggest that our results provide a conservative estimate of mortality differences by insurance status.

Finally, we evaluated the effect of missing values and mismatching on our conclusions about the contribution of C-section births to the mortality differences by insurance status. To limit the problem of mismatching and missing values in the covariates, we constructed a dataset with health insurance status and delivery mode only. These models confirmed that C-section was associated with higher NMR than vaginal birth (RR 1.54 [95%CI 1.50-1.58]). Furthermore, we checked if missing values in delivery mode could explain the higher risk of death among C-section births. Even when using the extreme assumption that all deaths with missing values for delivery mode were attributable to vaginal deliveries and all births with such missing values to C-section births, C-section delivery was associated with excess mortality (RR 1.41 [95%CI 1.38-1.45]).

Interpretation

The higher mortality risk associated with being uninsured or belonging to the subsidized scheme was substantially attenuated after adjusting for socioeconomic and demographic factors. By contrast, socioeconomic indicators such as maternal education remained strong predictors of neonatal mortality in models that controlled for health insurance status (Table 2). This implies that universal health insurance may not be sufficient to close the gap in newborn mortality between socioeconomic groups. Additional barriers to care seeking, such as supply-side problems,[17] may affect the poor more; and other factors, such as poverty, knowledge and health related behaviors, might contribute to higher neonatal mortality among the lower socioeconomic groups. Furthermore, differences in socioeconomic measures may explain only part of the difference in NMR between insurance schemes, as individuals in each scheme are relatively heterogeneous in terms of socioeconomic background. The small remaining excess mortality among the uninsured and subsidized scheme after adjusting for confounding might be reflective of differences in access to or quality of care. Although 98% of women deliver in a health facility assisted by a doctor, insufficient provision of services or distance to facilities especially affecting the uninsured may still contribute to higher neonatal mortality.[17, 18, 29-31] It is noteworthy that half of the mortality difference between infants born to uninsured mothers and those in the contributory scheme was attributable to deaths in the first 24 hours after birth. Furthermore, the differences were largest

for disorders related to respiratory distress during delivery, suggesting that quality of care during delivery may play a role in explaining excess mortality.

We found that mortality differences by insurance status would have been larger if babies of uninsured mothers and those in the subsidized scheme had the same C-section rate as mothers in the contributory scheme. C-sections were associated with birth before 39 weeks of gestational age, lower birth weight, and higher newborn mortality. Prematurity is the leading cause of newborn death worldwide[19, 32]; even births at 37 to 39 weeks have sub-optimal outcomes and C-section is not recommended before 39 weeks unless medically necessary.[33] Furthermore, low birth weight babies are on average 20 times more likely to die than heavier babies.[34] In Colombia, vital registration system data suggest that there has been a sharp rise in the fraction of C-section deliveries during the period of health insurance coverage expansion (Figure 1). Unfortunately, we had no data on whether the C-sections were medically necessary or elective; possibly, C-sections were associated with a lower risk of stillbirth (neonatal death and stillbirth are competing risks). In addition, higher NMR rates in C-section deliveries partially reflect selection - the fact that high risk pregnancies, which bring a potential health risk for the baby, often end up in C-section. However, C-section rates are exceptionally high in Colombia[35] and other Latin American countries, where a large proportion of C-sections is known to be elective.[33, 36] Our finding that C-section delivery is associated with higher newborn mortality corresponds with other studies in settings with very high C-section rates.[36] While medically indicated C-sections can save newborn lives, unnecessary C-sections may pose unnecessary risks for newborn survival.[37] Barros et al,[38] for instance, report a stagnation in the newborn mortality decline in urban Brazil because of an increase in preterm births caused by a strong increase in induced labor and C-section rates. These authors conclude that in Brazil, excessive medicalization led by an unregulated private sector drives these trends.[38] Likewise, fee-for-service payments may contribute to high C-section rates in Colombia, which favor contributory scheme patients, offsetting potentially positive health effects of improved access to maternity care through health insurance.

Conclusions

Our study is important in the light of many low- and middle-income countries currently undergoing major health care reform. Statutory free maternity care may contribute to better

newborn survival, as suggested by the small mortality differences between insurance status groups after adjusting for confounders. While maternity care in Colombia is free for all, in practice, differences in access to and quality of care between insurance status groups remain.[30] Further studies are warranted to establish whether contributory health insurance may be associated with higher rates of unindicated C-sections, and whether the latter may have increased neonatal mortality for babies in the contributory scheme.

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Conflict of interest statements

There are no conflicts of interest related to this paper.

Contribution to authorship

TAJH and IA conceived the paper; TAJH, IA and MA developed the analysis strategy; IA carried out the analyses under the supervision of MA; TAJH, IA and MA collectively interpreted the findings and wrote up the work. AB contributed to the interpretation of the findings and revision of the manuscript. All authors have read and approved the final manuscript.

Ethics committee approval

This article is based on secondary analysis of data on deaths and population counts in aggregate form made publically available by the National Statistics Office in Colombia. Ethical approval for this study was not required.

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Figure 1. Trends in health insurance coverage among women giving birth and C-section delivery, national vital registration system data, Colombia 1999-2011

Table 1. Distribution of live births by risk factors for neonatal death by health insurance status, Colombia, 2008-2011

	HEALTH INSURANCE STATUS							
	Contributory scheme (40% of live births)		Subsidized scheme (47% of live births)		Uninsured (11% of live births)		TOTAL	
	Live births	%	Live births	%	Live births	%	Live births	%
Distribution by insurance scheme	990,495	100%	1,183,741	100%	268,990	100%	2,506,920	100%
Year								
2008	251,720	25%	288,902	24%	79,581	30%	634,091	25%
2009	246,256	25%	299,368	25%	73,802	27%	634,740	25%
2010	240,899	24%	284,047	24%	65,603	24%	607,107	24%
2011	251,620	25%	311,424	26%	50,004	19%	630,982	25%
Sex of baby								
Male	509,203	51%	609,757	52%	138,849	52%	1,290,584	51%
Female	481,292	49%	573,984	48%	130,141	48%	1,216,336	49%
Maternal age								
19 years or less	136,965	14%	351,697	30%	89,726	33%	586,630	23%
20 to 34 years	730,261	74%	734,432	62%	162,120	60%	1,673,618	67%
35 years and more	123,269	12%	97,612	8%	17,144	6%	246,672	10%
Residence area of mother								
Urban	926,738	94%	805,746	68%	206,063	77%	1,998,008	80%
Rural	63,757	6%	377,995	32%	62,927	23%	508,912	20%
Marital status of mother								
Married	689,976	70%	675,743	57%	136,807	51%	1,554,347	62%
Not married	300,519	30%	507,998	43%	132,183	49%	952,573	38%
Maternal education								

Primary school or less	73,079	7%	396,692	34%	86,315	32%	559,597	22%
Lower secondary	206,748	21%	412,172	35%	92,778	34%	723,091	29%
Upper secondary	342,707	35%	331,561	28%	77,408	29%	774,596	31%
Tertiary education	367,961	37%	43,316	4%	12,489	5%	449,636	18%
Singleton/multiple birth								
Singleton	971,556	98%	1,163,313	98%	264,808	98%	2,462,120	98%
Multiple birth	18,939	2%	20,428	2%	4,182	2%	44,800	2%
Mode of delivery								
Vaginal delivery	505,624	51%	776,300	66%	193,116	72%	1,506,467	60%
C-section	484,871	49%	407,441	34%	75,874	28%	1,000,453	40%
Gestational age								
<32weeks	13,774	1%	14,178	1%	4,071	2%	32,834	1%
32-36 weeks	82,993	8%	82,783	7%	21,190	8%	191,665	8%
37-38 weeks	359,241	36%	355,832	30%	81,101	30%	817,583	33%
39-41 weeks	532,760	54%	720,892	61%	160,365	60%	1,450,597	58%
42 or more	1,727	0%	10,056	1%	2,263	1%	14,241	1%
Birth weight								
<1500g	12,240	1%	11,103	1%	3,196	1%	27,232	1%
1500- 2499g	83,634	8%	87,002	7%	22,349	8%	197,564	8%
2500-2999g	268,634	27%	297,107	25%	73,904	27%	655,002	26%
3000-3499g	418,366	42%	497,125	42%	111,249	41%	1,053,997	42%
3500-3999g	178,044	18%	242,381	20%	49,200	18%	482,839	19%
4000g or more	29,577	3%	49,023	4%	9,092	3%	90,286	4%

Panel 1. Neonatal mortality rate (number of deaths under 28 days per 1,000 live births) by health insurance status, total and by age-at-death and cause-of-death, Colombia 2008-2011

BY AGE-AT-DEATH

	Contributory scheme	Subsidized scheme	Uninsured	TOTAL
Less than one hour	0.63	0.89	1.04	0.79
Between 1-23 hours	1.19	1.76	1.98	1.54
Between 1-6 days	2.37	2.75	3.05	2.60
Between 7-27 days	1.94	2.29	2.31	2.13
TOTAL	6.13	7.69	8.38	7.07

BY CAUSE-OF-DEATH

Table 2. Association between health insurance status and neonatal mortality (RR with 95%CI), Colombia 2008-2011

	Model 1	Model 2	Model 3	Model 4
HEALTH INSURANCE STATUS				
Contributive (Ref)	1	1	1	1
Subsidized	1.27 (1.22 , 1.31)	1.09 (1.05 , 1.14)	1.17 (1.12 , 1.22)	1.20 (1.15 , 1.25)
Uninsured	1.36 (1.30 , 1.43)	1.16 (1.10 , 1.23)	1.27 (1.20 , 1.35)	1.20 (1.14 , 1.28)
YEAR				
2008	1.06 (1.01 , 1.10)	1.01 (0.97 , 1.06)	1.04 (1.00 , 1.08)	1.07 (1.03 , 1.12)
2009	1.02 (0.97 , 1.06)	0.99 (0.95 , 1.04)	1.01 (0.97 , 1.05)	1.02 (0.98 , 1.06)
2010	0.94 (0.90 , 0.98)	0.93 (0.89 , 0.97)	0.94 (0.90 , 0.98)	0.95 (0.91 , 1.00)
2011 (ref)	1	1	1	1
MATERNAL AGE				
19 years or less	1.08 (1.04 , 1.12)	0.94 (0.90 , 0.98)	0.94 (0.91 , 0.98)	0.83 (0.80 , 0.87)
20-34 years (Ref)	1	1	1	1
35 years and more	1.25 (1.19 , 1.31)	1.23 (1.18 , 1.30)	1.18 (1.12 , 1.23)	1.00 (0.95 , 1.05)
SEX				
Female (Ref)	1	1	1	1
Male	1.26 (1.23 , 1.30)	1.26 (1.23 , 1.30)	1.25 (1.22 , 1.29)	1.29 (1.25 , 1.33)
SINGLETON/MULTIPLE BIRTH				
Singleton (Ref)	1	1	1	1
Multiple birth	4.00 (3.76 , 4.24)	3.99 (3.76 , 4.24)	3.17 (2.98 , 3.36)	0.59 (0.55 , 0.62)
MATERNAL EDUCATION				
Lower secondary or less		1.54 (1.42 , 1.68)	1.60 (1.47 , 1.74)	1.57 (1.44 , 1.71)
Upper secondary or post-secondary (Ref)			1	1
MARITAL STATUS				
Married (Ref)		1	1	1

	Model 1	Model 2	Model 3	Model 4
Non-married		1.26 (1.21 , 1.30)	1.25 (1.21 , 1.30)	1.11 (1.07 , 1.14)
RESIDENCE AREA				
Rural (Ref)		1	1	1
Urban		0.88 (0.84 , 0.92)	0.92 (0.88 , 0.95)	0.94 (0.90 , 0.98)
MODE OF DELIVERY				
Vaginal delivery (Ref)			1	1
C-section			1.75 (1.69 , 1.80)	1.05 (1.02 , 1.09)
GESTATIONAL AGE				
Preterm				6.21 (5.95 , 6.49)
Term or post-term (Ref)				1
BIRTH WEIGHT				
Low birth weight				7.54 (7.21 , 7.88)
Normal or high birth weight (Ref)				1

All models control for region (Bogota district capital and 32 departments).

Variables in the models:

Model 1: health insurance status, region, year, maternal age, sex, singleton/multiple birth

Model 2: health insurance status, region, year, maternal age, sex, singleton/multiple birth, maternal education, marital status, residence area

Model 3: health insurance status, region, year, maternal age, sex, singleton/multiple birth, maternal education, marital status, residence area, mode of delivery

Model 4: health insurance status, region, year, maternal age, sex, singleton/multiple birth, maternal education, marital status, residence area, mode of delivery, gestational age, birth weight

Table 3. Distribution (%) of birth weight and gestational age at birth by health insurance status and mode of delivery, Colombia 2008-2011

	Contributory scheme		Subsidized scheme		Uninsured		Population
	Vaginal	C-section	Vaginal	C-section	Vaginal	C-section	
GESTATIONAL AGE AT BIRTH							
< 32weeks	0.7%	2.1%	0.8%	1.9%	1.1%	2.5%	32,023
32-36 weeks	5.7%	11.2%	5.4%	10.0%	6.6%	11.0%	186,966
37-38 weeks	31.5%	41.3%	27.6%	34.8%	28.7%	33.7%	796,174
39-41 weeks	62.0%	45.2%	65.4%	52.4%	62.7%	51.8%	1,414,017
42 or more	0.2%	0.2%	0.8%	0.9%	0.8%	1.0%	14,046
Total							2,443,226
BIRTH WEIGHT							
< 1500g	0.5%	2.0%	0.5%	1.7%	0.7%	2.3%	26,539
1500-2499g	6.1%	10.9%	5.7%	10.4%	6.9%	11.9%	192,985
2500-2999g	28.9%	25.2%	25.5%	24.4%	28.1%	25.9%	639,645
3000-3499g	45.3%	39.1%	43.8%	38.5%	43.1%	37.0%	1,026,740
3500-3999g	17.1%	18.9%	20.7%	20.1%	18.2%	18.5%	469,625
4000g or more	2.2%	3.8%	3.7%	4.9%	3.0%	4.4%	87,692
Total							2,443,226

Vaginal: vaginal delivery; C-section: C-section delivery.

Figure 2. Association between health insurance status and C-section delivery (odds ratios with 95%CI), Colombia 2008-2011

Variables in the models:

Model 1: health insurance status, region, year, maternal age, sex, singleton/multiple birth

Model 2: health insurance status, region, year, maternal age, sex, singleton/multiple birth, maternal education, marital status

Full models are presented in Appendix table 4.

Table S1. Causes of death in this study according International Classification of Diseases (ICD-10)

Chapter	Blocks	Title	Cause of death in this paper	CIE-10 codes
XVI	P00-P96	Certain conditions originating in the perinatal period	Certain conditions arising fetal growth and birth	P00-P01, P03-P05, P07, P10-P15
			Respiratory disorders specific to the perinatal period	P20-P28
			Infections specific to the perinatal period	P35-P39
			Other conditions originating in the perinatal period	P08, P29, P50-P61, P70-P74, P76-P78-P96
XVII	Q00-Q99	Congenital malformations, deformations and chromosomal abnormalities	Congenital and chromosomal abnormalities	Q00-Q18, Q20-Q28, Q30-Q99
I-XV	A00-O99		Remaining causes of death	A00-O99
XVIII-XIX	R00-Y98			R00-Y89.9

Figure S1: A conceptual framework of the relationships between health insurance status and neonatal mortality

Table S2. Association between health insurance status and cause-specific neonatal mortality (RR with 95%CI), Colombia 2008-2011

	Model 1	Model 2	Model 3	Model 4
<u>Certain conditions arising fetal growth and birth</u>				
Contributory (Ref)	1	1	1	1
Subsidized	1.19 (1.07 , 1.32)	1.02 (0.91 , 1.13)	1.07 (0.96 , 1.20)	1.11 (0.99 , 1.24)
Uninsured	1.42 (1.24 , 1.63)	1.20 (1.04 , 1.40)	1.29 (1.11 , 1.49)	1.20 (1.03 , 1.39)
<u>Respiratory disorders specific to the perinatal period</u>				
Contributory (Ref)	1	1	1	1
Subsidized	1.42 (1.33 , 1.51)	1.22 (1.14 , 1.31)	1.27 (1.19 , 1.36)	1.31 (1.22 , 1.40)
Uninsured	1.61 (1.48 , 1.75)	1.37 (1.25 , 1.50)	1.45 (1.32 , 1.59)	1.36 (1.24 , 1.49)
<u>Infections specific to the perinatal period</u>				
Contributory (Ref)	1	1	1	1
Subsidized	1.39 (1.25 , 1.54)	1.20 (1.07 , 1.35)	1.29 (1.15 , 1.45)	1.33 (1.18 , 1.49)
Uninsured	1.26 (1.08 , 1.47)	1.07 (0.92 , 1.26)	1.19 (1.01 , 1.39)	1.12 (0.96 , 1.31)
<u>Other conditions originating in the perinatal period</u>				
Contributory (Ref)	1	1	1	1
Subsidized	1.17 (1.06 , 1.28)	1.03 (0.93 , 1.15)	1.10 (0.99 , 1.23)	1.13 (1.02 , 1.26)
Uninsured	1.30 (1.14 , 1.48)	1.14 (0.99 , 1.31)	1.24 (1.07 , 1.43)	1.17 (1.02 , 1.35)
<u>Congenital and chromosomal abnormalities</u>				
Contributory (Ref)	1	1	1	1
Subsidized	1.09 (1.02 , 1.17)	0.94 (0.87 , 1.02)	1.06 (0.98 , 1.15)	1.07 (0.99 , 1.16)
Uninsured	1.05 (0.94 , 1.16)	0.89 (0.80 , 0.99)	1.04 (0.93 , 1.16)	1.00 (0.90 , 1.11)
<u>Remaining causes of death</u>				
Contributory (Ref)	1	1	1	1
Subsidized	2.25 (1.74 , 2.91)	1.77 (1.35 , 2.33)	1.82 (1.38 , 2.40)	1.86 (1.41 , 2.45)
Uninsured	3.34 (2.43 , 4.57)	2.63 (1.89 , 3.66)	2.73 (1.96 , 3.80)	2.64 (1.90 , 3.67)

All models control for region (Bogota district capital and 32 departments).

Variables in the models:

Model 1: health insurance status, region, year, maternal age, sex, singleton/multiple birth

Model 2: health insurance status, region, year, maternal age, sex, singleton/multiple birth, maternal education, marital status, residence area

Model 3: health insurance status, region, year, maternal age, sex, singleton/multiple birth, maternal education, marital status, residence area, mode of delivery

Model 4: health insurance status, region, year, maternal age, sex, singleton/multiple birth, maternal education, marital status, residence area, mode of delivery, gestational age, birth weight

Table S3. Association between health insurance status and neonatal mortality for five major Colombian regions (RR with 95%CI), 2008-2011

	Model 1	Model 2	Model 3	Model 4
HEALTH INSURANCE STATUS				
Contributory (Ref)	1	1	1	1
Subsidized	1.27 (1.21 , 1.33)	1.09 (1.03 , 1.15)	1.18 (1.11 , 1.24)	1.19 (1.13 , 1.26)
Uninsured	1.41 (1.32 , 1.51)	1.21 (1.13 , 1.30)	1.33 (1.24 , 1.43)	1.27 (1.18 , 1.36)
YEAR				
2008	1.04 (0.98 , 1.11)	0.99 (0.94 , 1.06)	1.02 (0.97 , 1.09)	1.07 (1 , 1.13)
2009	0.95 (0.90 , 1.01)	0.93 (0.88 , 0.99)	0.95 (0.89 , 1.01)	0.97 (0.91 , 1.03)
2010	0.90 (0.85 , 0.96)	0.89 (0.84 , 0.95)	0.90 (0.85 , 0.96)	0.92 (0.87 , 0.98)
2011 (ref)	1	1	1	1
MATERNAL AGE				
19 years or less	1.05 (1.00 , 1.11)	0.92 (0.87 , 0.98)	0.94 (0.89 , 1.00)	0.83 (0.79 , 0.88)
20-34 years (Ref)	1	1	1	1
35 years and more	1.32 (1.24 , 1.41)	1.30 (1.21 , 1.39)	1.21 (1.13 , 1.29)	1.04 (0.97 , 1.11)
SEX				
Female (Ref)	1	1	1	1
Male	1.25 (1.20 , 1.31)	1.25 (1.20 , 1.31)	1.24 (1.19 , 1.30)	1.28 (1.23 , 1.34)
SINGLETON/MULTIPLE BIRTH				
Singleton (Ref)	1	1	1	1
Multiple birth	4.88 (4.51 , 5.28)	4.89 (4.52 , 5.29)	3.62 (3.35 , 3.93)	0.70 (0.65 , 0.76)
MATERNAL EDUCATION				
Lower secondary or less		1.57 (1.44 , 1.72)	1.63 (1.49 , 1.78)	1.60 (1.46 , 1.74)
Upper secondary or post-secondary (Ref)			1	1
MARITAL STATUS				

	Model 1	Model 2	Model 3	Model 4
Married (Ref)		1	1	1
Non-married		1.18 (1.13 , 1.24)	1.19 (1.13 , 1.24)	1.06 (1.01 , 1.11)
RESIDENCE AREA				
Rural (Ref)		1	1	1
Urban		0.92 (0.85 , 0.99)	0.95 (0.88 , 1.02)	1.01 (0.94 , 1.09)
MODE OF DELIVERY				
Vaginal delivery (Ref)			1	1
C-section			2.04 (1.95 , 2.14)	1.16 (1.11 , 1.21)
GESTATIONAL AGE				
Preterm				6.47 (6.07 , 6.90)
Term or post-term (Ref)				1
BIRTH WEIGHT				
Low birth weight				7.55 (7.07 , 8.07)
Normal or high birth weight (Ref)				1

All models control for the regions included (Antioquia, Atlántico, Bogotá D. C., Cundinamarca, and Valle).

Variables in the models:

Model 1: health insurance status, region, year, maternal age, sex, singleton/multiple birth

Model 2: health insurance status, region, year, maternal age, sex, singleton/multiple birth, maternal education, marital status, residence area

Model 3: health insurance status, region, year, maternal age, sex, singleton/multiple birth, maternal education, marital status, residence area, mode of delivery

Model 4: health insurance status, region, year, maternal age, sex, singleton/multiple birth, maternal education, marital status, residence area, mode of delivery, gestational age, birth weight

Table S4. Association between health insurance status and C-section delivery (odds ratios with 95%CI), Colombia 2008-2011

	Model 1	Model 2
HEALTH INSURANCE STATUS		
Contributory (Ref)	1	1
Subsidized	0.76 (0.75 , 0.77)	0.81 (0.80 , 0.82)
Uninsured	0.61 (0.60 , 0.62)	0.66 (0.65 , 0.67)
SEX		
Female (Ref)	1	1
Male	1.03 (1.02 , 1.04)	1.03 (1.02 , 1.04)
YEAR		
2008	0.84 (0.83 , 0.85)	0.84 (0.83 , 0.86)
2009	0.89 (0.88 , 0.91)	0.89 (0.88 , 0.91)
2010	0.94 (0.93 , 0.96)	0.94 (0.93 , 0.96)
2011 (Ref)	1.00	1.00
MATERNAL AGE		
19 years or less	0.93 (0.92 , 0.94)	0.94 (0.93 , 0.95)
20-34 years (Ref)	1	1
35 years and more	1.21 (1.19 , 1.23)	1.23 (1.21 , 1.25)
SINGLETON/MULTIPLE BIRTH		
Singleton (Ref)	1	1
Multiple birth	4.37 (4.24 , 4.49)	4.41 (4.29 , 4.54)
RESIDENCE AREA		
Urban (Ref)		1
Rural		0.76 (0.75 , 0.77)
MATERNAL EDUCATION		
Primary		0.76 (0.75 , 0.78)
Lower secondary		0.90 (0.88 , 0.91)
Upper secondary		0.98 (0.96 , 0.99)
Tertiary level (Ref)		1
MARITAL STATUS		
Married (Ref)		1
Non-married		1.02 (1.01 , 1.03)

Both models control for region (Bogota district capital and 32 departments).

Variables in the models:

Model 1: health insurance status, region, year, maternal age, sex, singleton/multiple birth

Model 2: health insurance status, region, year, maternal age, sex, singleton/multiple birth, maternal education, marital status