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Implementation of the Zambia Electronic Perinatal Record System for comprehensive prenatal and delivery care

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Abstract

Objective—To characterize prenatal and delivery care in an urban African setting.

Methods—The Zambia Electronic Perinatal Record System (ZEPRS) was implemented to record demographic characteristics, past medical and obstetric history, prenatal care, and delivery and newborn care for pregnant women across 25 facilities in the Lusaka public health sector.

Results—From June 1, 2007, to January 31, 2010, 115 552 pregnant women had prenatal and delivery information recorded in ZEPRS. Median gestation age at first prenatal visit was 23 weeks (interquartile range [IQR] 19–26). Syphilis screening was documented in 95 663 (83%) pregnancies: 2449 (2.6%) women tested positive, of whom 1589 (64.9%) were treated appropriately. 111 108 (96%) women agreed to HIV testing, of whom 22% were diagnosed with HIV. Overall, 112 813 (98%) of recorded pregnancies resulted in a live birth, and 2739 (2%) in a stillbirth. The median gestational age was 38 weeks (IQR 35–40) at delivery; the median birth weight of newborns was 3000 g (IQR 2700–3300 g).

Conclusion—The results demonstrate the feasibility of using a comprehensive electronic medical record in an urban African setting, and highlight its important role in ongoing efforts to improve clinical care.

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Conflict of interest

The authors have no conflicts of interest.

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Keywords

Electronic medical record; Newborn care; Perinatal audit; Prenatal care; Sub-Saharan Africa

1. Introduction

Pregnancy, delivery, and the early postpartum period are associated with high health risks for many women in low-income countries [1]. Perinatal audit—the cyclic process in which causes of adverse outcomes are identified and targeted interventions are implemented to address them—has been shown to improve outcomes across various settings, including those in Sub-Saharan Africa [2,3]. Although favorable outcomes have been achieved with only modest investments in auditing systems (e.g. weekly hospital review panels), such approaches may be insufficient in more complex medical systems. In many African settings, for example, patients carry their own medical records—an arrangement that challenges the reliable measurement of facility-based outcomes. At the facility level, visits are often documented only via registers, which can be burdensome to review systematically and might contain only basic medical information [4]. The data collation process can also be inaccurate and misrepresent actual site performance [5].

In these situations, the use of electronic medical records (EMRs) holds promise [6,7]. Routinely collected data can be queried to generate reports about site or provider performance, and to identify common characteristics of adverse perinatal events. Such systems can also enhance the standardization, quality, and completeness of medical documentation, which is essential to ongoing quality care [8]. Unfortunately, such sophisticated resources are rarely available in resource-constrained settings [9], where the occurrence of most adverse obstetric outcomes is highest.

Like most Sub-Saharan countries, Zambia is affected by shortages in healthcare providers [10]. The population of Lusaka, the capital city of Zambia, was estimated at 1.1 million in the 2000 census [11]; however, there has been considerable growth and expansion in the past decade. HIV prevalence in the prenatal population is estimated at 21%, a figure that has declined in recent years [12]. Estimates of maternal mortality rates in Lusaka are high and consistent with other parts of the country [13,14]. In such settings, innovative approaches to perinatal audit are vital for addressing the multitude of challenges associated with high disease burden and resource constraints [13,14].

The aim of the present study was to test the design and implementation of an EMR system, the Zambia Electronic Perinatal Record System (ZEPRS), in Lusaka, an urban African setting.

2. Materials and methods

In the present cross-sectional study, data collected from pregnant women seeking prenatal care and delivery services in the Lusaka public health sector were entered in the ZEPRS database. The analysis cohort included pregnancies from June 1, 2007, to January 31, 2010, for which medical information was collected during prenatal care (for at least one visit) and around the time of delivery. The start date of the cohort was set to June 1, 2007, to maximize data capture for enrolled patients; before this date, not all sites had fully implemented the ZEPRS data system. Use of these routinely collected data was approved by the ethical review committees at the University of Zambia (Lusaka, Zambia) and the University of Alabama at Birmingham (Birmingham, AL, ACCEPTED MANUSCRIPT USA).

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The design of ZEPRS began in 2004 with funding from the Bill and Melinda Gates Foundation. A team of Zambian and expatriate experts was formed from the University Teaching Hospital, Lusaka Urban District Health Management Team, Centre for Infectious Disease Research in Zambia, University of Alabama at Birmingham, and RTI International. A careful field assessment of Lusaka's public sector was performed and, on the basis of this evaluation, the software framework for ZEPRS was developed.

The ZEPRS application employs "real-time" data entry, whereby registered users (e.g. nurses, midwives, and clerical staff) directly enter information from each patient visit at the point of care (Table 1). Pre-programmed "checks" prevent the entry of nonsense values; abnormal (but plausible) findings trigger alerts, so that providers can either correct the data entry (if a mistake was made) or intervene as needed. To ensure that ZEPRS was fully integrated into the Zambian Ministry of Health's nationwide reporting system (the "Health Management Information System"), automated programs were developed to generate and print pre-populated prenatal records, registers, and reports. This feature allows personnel to dedicate more time to the care of individual patients and less time to the lengthy process of weekly and monthly tally counts. To ensure continuity of care between pregnancies, we worked closely with the Ministry of Health to implement standard identification numbers linked to the patient, rather than to each individual pregnancy. ZEPRS has the provision for entering subsequent pregnancies; data on past pregnancies are archived but accessible. At time of birth, the system generates unique identification numbers specifically for infants, and these are linked to the mother's record. This ensures a continuity of care for these children and links infant outcomes to the mother's prenatal course.

Because patients frequently move from site to site during prenatal care and for delivery, a network-based system with central data storage was developed [15,16]. A city-wide wireless network was implemented across Lusaka, so that all medical information can be maintained from a central server and retrieved regardless of location. Individual patient data are secured via Lightweight Extensible Authentication Protocol (LEAP; Cisco Systems; San Jose, CA, USA), coupled with a Radius server and WEP 128-bit encryption on the wireless links. Other infrastructure investments include computers for entering and accessing patient record information; internet telephony for inter-facility communication; back-up battery supplies for short-term power outages; and a back-up "mirrored" server in case of system failure.

To maximize data security, all users undergo training in patient confidentiality and must sign confidentiality agreements before they are registered with individualized logins and passwords. The platform requires password confirmation at certain points in data entry and has automatic logout provisions when the application is idle for more than 10 minutes. System security is based on commercially available anti-virus software that is updated regularly at the facility level. All staff are trained in the regular use of ZEPRS. Workshops range from 2 to 10 days and focus on basic (e.g. hardware orientation, word processing) to application-specific skills (e.g. data entry, record retrieval).

Data quality is assessed regularly. On a monthly basis, duplicate entries and internal data inconsistencies are flagged. Where possible, these issues are resolved centrally by a data coordinator; issues that require further investigation are reviewed at the site by clerical staff and district nurses. Site staff also perform monthly data audits comparing aggregated ZEPRS data to statistics collected by government clinic registers. When significant discrepancies arise, more comprehensive audits are performed to resolve discrepancies between the 2 data sources.

Field testing of ZEPRS began in November 2005 at 3 sites in Lusaka. On the basis of user feedback, several innovations were made before the broader implementation of the system.

At larger prenatal clinics, for example, the high patient-to-provider ratio prohibited real-time entry of medical information by health providers alone. Instead, dedicated clerical staff were hired to support data entry at specific points within the clinic (e.g. during patient registration). A back-up system using paper documentation was developed for periods of prolonged power and/or network outages; these records were then entered into ZEPRS when the system was restored. With these modifications, ZEPRS was expanded in a phased approach. By June 2007, it had been implemented across 25 Lusaka prenatal care clinics (23 government primary care clinics, 1 private facility, and the University Teaching Hospital), 13 of which are delivery centers (11 government sites, 1 private facility, and the University Teaching Hospital).

To assess the utility of ZEPRS, routinely collected demographic and obstetric characteristics of the study cohort were analyzed, including aggregate details regarding prenatal care, labor, and delivery. Continuous variables were reported by median and interquartile range (IQR) and then categorized. Estimated gestation age was calculated by last menstrual period for pregnancies that were less than 20 weeks at time of enrollment. For pregnancies at or more than 20 weeks at enrollment, both last menstrual period and physical examination (i.e., fundal height) were used; if these 2 methods yielded gestational ages that were within 3 weeks of each other, the date based on the last menstrual period was used. If not, then the fundal height-derived gestational age was used. Histograms were developed to show the distribution of gestational age at enrollment and delivery, and to describe birth weight. Pregnancy losses were considered spontaneous abortions if they were 28 weeks or less, and stillbirths if they were more than 28 weeks [17]. Descriptive analyses were performed with SAS version 9.13 (SAS Institute, Cary, NC, USA).

3. Results

The expansion of ZEPRS across the Lusaka district began in February 2006 via a phased approach and reached full implementation by June 2007. From June 1, 2007, to January 31, 2010, a total of 178 844 pregnancies had been recorded during prenatal care, and 116 675 deliveries had been entered into the database. In the present study, the descriptive analysis is limited to pregnancies with complete medical information recorded for delivery and at least 1 prenatal visit.

Of the 176 754 pregnancies with complete information for at least 1 prenatal visit, 61 202 (34.6%) had no delivery information—many of them were still in early pregnancy—and were thus excluded from the analysis. Of the 116 675 deliveries, 1123 (1.0%) had no record of prenatal care in ZEPRS and were similarly excluded (Figure 1). Among the 115 552 pregnancies in the analysis cohort, 1088 (1.0%) represented repeat pregnancies entered into ZEPRS—that is, either the second (n=1086) or the third (n=2) pregnancy for the same woman. Median gestation age at the first prenatal visit was 23 weeks (IQR 19–26; Figure 2A). Other demographic and medical characteristics at time of enrollment are given in Table 2.

There were several notable findings across ZEPRS-supported sites (Table 3). Among the 60 657 pregnancies with data for 2 or more clinical visits, 5779 (9.5%) had documented prenatal visits at 2 facilities, whereas only 68 (0.1%) had documented visits at 3 or more facilities. Syphilis screening was documented in 95 663 of 115 552 (82.8%) pregnancies; 2449 (2.6%) of the women tested positive by rapid plasma reagin assay. Only 1589 of these 2449 (64.9%) women had single-dose penicillin treatment—the local standard of care—documented in ZEPRS. The Lusaka district's policy of "opt-out" HIV testing [18] accomplished high rates of screening: more than 95% agreed to HIV testing, of whom approximately 22% were diagnosed with HIV infection. Nearly 80% (18 928 of 23 932) of women diagnosed with HIV during pregnancy underwent CD4-positive screening for antiretroviral therapy eligibility. Half (9419 of 18 928) of these women met the CD4-positive criteria of less than 350 cells/μL to initiate HIV treatment.

Overall, 112 813 of 115 552 (97.6%) deliveries resulted in a live birth, and 2739 deliveries were categorized as stillbirth, giving a rate of 24 stillbirths per 1000 deliveries (95% confidence interval, 23–25). Documentation of induced labor was exceedingly rare (n=438, 0.5%). Caesarean delivery was performed in 4697 (4.1%) of women with mode of delivery documented. Median birth weight of the newborn was 3000 g (IQR 2700–3300 g; Figure 2C). Other characteristics of labor and delivery are given in Table 3.

4. Discussion

The present study has demonstrated the successful design and implementation of a comprehensive electronic perinatal record system in an urban African setting. Now fully utilized across the Lusaka public sector, ZEPRS has the capacity for enhanced monitoring and evaluation of prenatal and newborn care. Many notable findings from this descriptive analysis could not be quantified by the previous system of patient-held prenatal records and clinic-based registers.

Much has been written about the challenges inherent to register-based information systems for program monitoring and management. Work by Mate et al. [5] in South Africa, for example, demonstrated gross inconsistencies between monthly tally reports and data audits designed to verify program statistics. In a review of 6 core indicators for prevention of mother-to-child HIV transmission services, independent teams found that monthly reports were complete only 50% of the time and accurate (i.e. within 10% of reconstructed values) only 13% of the time, features that they attributed to poor data collation on site [5]. According to focus groups in South Africa, data collation was viewed as highly burdensome among healthcare providers; few providers routinely used these statistics to inform management decisions at the site level [4]. Similar trends have been noted in other areas of health provision, including adult HIV testing and childhood immunizations [19,20].

By standardizing data collection and linking antecedent medical information to later outcomes, ZEPRS has the capacity for sophisticated queries far out of the reach of previous paper-based systems. Although greater investments in time are needed at the time of data entry, reports can be automated to provide quick updates of site performance. The framework of ZEPRS also permits careful evaluation of health services. Problem areas such as syphilis treatment—estimated at only 65% in the present analysis—are easily identified through regular performance audits and can be used to guide further investigation into potential causes at the health system (e.g. supply interruptions), facility (e.g. staff shortages), or even provider (e.g. clinical oversight) levels. By regularly auditing these clinical indicators, strategies to correct specific deficiencies can be carefully assessed and, where needed, modified. Although promising, such strategies require rigorous and formal evaluation; such work is beyond the scope of the current analysis.

In the present study, the ZEPRS database has been analyzed to provide a well-characterized description of pregnant women and their newborn infants seeking care in Lusaka government clinics. An unexpectedly high proportion of women receiving prenatal care in Lusaka public health clinics appeared to deliver outside the government system, either in private hospitals or at home, or outside the city itself. Of the 176 754 pregnancies with at least 1 prenatal visit entered in ZEPRS, roughly a fifth were at 44 weeks gestation or more and yet had no record of delivery. This is concerning from a clinical perspective, given the known association between non-institutional delivery and poor obstetric outcomes [21].

Such attrition also negatively affects our ability to monitor outcomes at a population level, particularly for rare conditions such as stillbirth and maternal death.

In the present evaluation, digit preferences among health providers were noted in 2 key fields, namely, estimated gestational age at enrollment (for even-numbered weeks; Figure 2A) and birth weight (at 2000 grams and 3000 grams; Figure 2C). This clustering is unlikely to have a significant impact on individual clinical care; however, further investigation is needed to understand the extent of potential entry bias and the quality of ascertained data.

Although the implementation of ZEPRS has been successful, it has not been without challenges. It is possible to cope with short-term power interruptions, but seasonal scheduled "black-outs" by power companies have led to greater reliance on a less efficient paper back-up system. To maximize network stability, a dedicated team has been employed to trouble-shoot problems arising from power interruptions, weather, and hardware malfunctions. An "off-line" mode is planned for the next ZEPRS upgrade, so that data entered during network outages are stored locally and uploaded automatically once the wireless signal is restored. Efficient patient and information flow has required ongoing review and optimization. Full-time data clerks have been stationed at large facilities, where they support entry of medical information. We are also working to link ZEPRS to a web-based laboratory platform, so that users can quickly and easily retrieve missing test results.

The issue of long-term sustainability must also be addressed. At present, ZEPRS is maintained through funding from the Zambian government and international donors, primarily within the context of service provision. A demonstration of the effectiveness and cost-effectiveness of ZEPRS as part of a comprehensive program-monitoring package would be a compelling justification for long-term support. In the meantime, we are working to enhance provider efficiency and to reduce hardware and/or infrastructure costs. The promising operations research framework provided by ZEPRS has also been successfully leveraged to fund ongoing development and supplement maintenance costs. Ultimately, a key factor to the long-term success of EMRs is the engagement of local policy-makers. We are encouraged by the Zambian Ministry of Health's substantial track record with technology-based health innovations.

In summary, the feasibility of a comprehensive EMR in an urban African setting has been demonstrated by the implementation of ZEPRS. In the present study, the platform has been used to characterize the prenatal and newborn populations in Lusaka and to provide basic data regarding patient outcomes. With continued optimization, we see a greater role for this data system in improving healthcare. However, the impact and cost-effectiveness of ZEPRS require formal evaluation to understand better its role in improving maternal and child outcomes.

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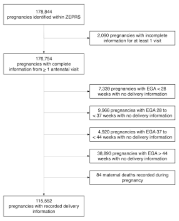
178,844
pregnancies identified within ZEPRS
2,090 pregnancies with incomplete information for at least 1 visit
176,754
pregnancies with complete information from ≥ 1 antenatal visit
7,339 pregnancies with EGA < 28 weeks with no delivery information
9,966 pregnancies with EGA 28 to < 37 weeks with no delivery information
4,920 pregnancies with EGA 37 to < 44 weeks with no delivery information
38,893 pregnancies with EGA > 44 weeks with no delivery information
84 maternal deaths recorded during pregnancy
115,552
pregnancies with recorded delivery information

Figure 1.

Description of the study cohort with prenatal care and delivery information entered into the ZEPRS from June 1, 2007, to January 31, 2010. * The 38 893 pregnancies with no delivery information after 44 weeks represent non-institutional delivery, institutional delivery outside the ZEPRS-supported sites, and losses to follow-up. All gestational ages are based on dating information at the enrollment visit. EGA, estimated gestational age.

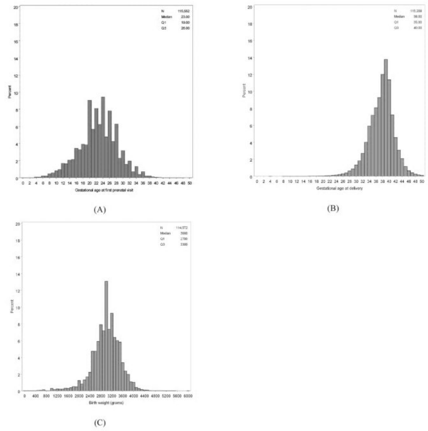

Figure 2.

Distribution of estimated gestation age and birth weight among pregnancies entered into the ZEPRS from June 1, 2007, to January 31, 2010. (A) Estimated gestation age at enrollment into prenatal care. (B) Estimated gestation age at time of delivery. (C) Birth weight at delivery.

Table 1

Medical information captured by ZEPRS

Category	Sample variables collected
Current pregnancy	Sample variables collected Estimated due date (calculated from last menstrual period, fundal height, and/or ultrasound); singleton or multiple gestation; pregnancy complications; prior history of HIV testing; maternal immunizations received; use of insecticide-treated bed net
Past obstetrical history	Gravidity; parity; date and site of past delivery; mode of delivery; duration of labor; pregnancy complications (e.g. infection, eclampsia, hemorrhage); sex of infant; infant birth weight; infant's current vital status
Past medical history	Review of symptoms; previous medical conditions, including hypertension, diabetes, asthma, heart disease, kidney disease, liver disease, thyroid disease, tuberculosis, HIV, and recent malaria; history of surgery, particularly pelvic surgery; drug allergies; past contraception use
Routine prenatal visit	Estimated gestational age; fundal height measurement; fetal lie, presentation, and descent; fetal heart rate; blood pressure measurement; maternal weight; full physical examination; HIV counseling and testing results (CD4 screening and result for those with HIV diagnosis); antiretroviral drug regimen prescribed; syphilis screening and test result; penicillin treatment administered; partner screening and treatment for HIV and syphilis; administration/ dispensation of routinely used drugs in pregnancy (e.g. iron, folate, mebendazole, sulfadoxine/pyrimethamine); results from routinely performed laboratory tests (e.g. hemoglobin, urine analysis, malaria blood smear)
Labor and delivery	Estimated gestational age; review of symptoms including contractions, fetal movement, vaginal bleeding, and ruptured membranes; fundal height measurement; fetal lie, presentation, and descent; blood pressure measurement; full physical examination; fetal heart rate; vaginal examination, including cervical dilation, effacement, and position; clinical pelvimetry measurements; medications used to induce or augment labor; mode of delivery; complications of labor (e.g. chorioamnionitis, prenatal or postpartum hemorrhage, pre-eclampsia or eclampsia, dystocia); date and time of birth; infant sex; infant birth weight; Apgar scores at 1, 5, and 10 minutes; neonatal resuscitation measurement used; neonatal physical examination; infant dosing for HIV prophylaxis

Table 2

Maternal and obstetric characteristics at enrollment for 115,552 pregnancies at sites supported by ZEPRS from June 1, 2007, to January 31, 2010

Characteristic	No. of pregnancies with data recorded	Value [a]
Age, years	115 552	25 (21–29)
<15 years		515 (0.4)
15–19 years		19 827 (17.2)
20–24 years		37 113 (32.1)
25–29 years		30 892 (26.7)
30–34 years		18 607 (16.1)
35–39 years		7227 (6.3)
≥40 years		1371 (1.2)
Education	99 655	
None		4070 (4.1)
Primary		43 580 (43.7)
Secondary		47 883 (48.0)
Tertiary		4122 (4.1)
Marital status	111 140	
Single		10 053 (9.0)
Married or cohabitating		100 542 (90.5)
Divorced or widowed		545 (0.5)
Number of prior pregnancies	115 552	1 (0–3)
None		33 669 (29.1)
1–2		29 221 (25.3)
3 or more		30 377 (26.3)
Prior history of cesarean delivery	81 883	3079 (3.8)
Prior history of spontaneous abortion	115 552	2738 (2.4)
Prior history of terminated pregnancy	115 552	88 (0.1)
Prior history of stillbirth	81 883	2181 (2.7)
Previous diagnosis of hypertension	98 584	1407 (1.4)
Previous diagnosis of diabetes mellitus	98 980	92 (0.1)
Previous diagnosis of heart disease	98 050	134 (0.1)
Previous diagnosis of HIV	95 825	4226 (4.4)
Gestational age at enrollment visit, weeks	115 552	23 (19–26)
<20 weeks		29 390 (25.4)
20–27 weeks		64 081 (55.5)
28–31 weeks		15 416 (13.3)
32–35 weeks		5048 (4.4)
≥36 weeks		1617 (1.4)
Weight, kg	96 772	59 (54–66)
BMI	68 631	24 (22–26)

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by the square of height in meters).

[a] Values are given as number (percentage) or median (IQR) unless otherwise indicated.

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Table 3

Characteristics of prenatal and delivery care for 115,552 pregnancies at sites supported by the ZEPRS from June 1, 2007, to January 31, 2010

Characteristic	**No. of pregnancies with data recorded**	**Value** [a]
Reported sleeping under insecticide-treated bed net	98 242	40 044 (40.8)
Screened for syphilis by RPR assay	95 663	
Non-reactive		93 214 (97.4)
Reactive		2449 (2.6)
Documented treatment for syphilis among those testing RPR-positive	2449	1589 (64.9)
Agreed to HIV testing	115 552	111 108 (96.2)
HIV test result missing	111 108	313 (0.3)
HIV test result reported to patient	111 108	110 795 (99.7)
HIV-positive result		23 932 (21.6)
HIV-negative result		86 863 (78.6)
Declined HIV testing, known HIV infection	4444	1296 (29.2)
CD4 screening among women diagnosed with HIV during pregnancy	23 932	18 928 (79.1)
CD4 cell count among HIV-infected women tested	18 928	352 (234–498)
≤200 cells/μL		3514 (18.6)
201–350 cells/μL		5905 (31.2)
351–500 cells/μL		4839 (25.6)
>500 cells/μL		4670 (24.7)
Antiretroviral prophylaxis prescribed among those diagnosed with HIV	23 850	
None		3209 (13.5)
Intrapartum nevirapine only		7988 (33.5)
Short-course zidvoduine and intrapartum nevirapine		8269 (34.7)
Three-drug combination therapy		4384 (18.4)
Gestational age in weeks at delivery, median (IQR)	112 051	38 (35–40)
<28 weeks		1558 (1.4)
28 to <32 weeks		5344 (4.8)
32 to <37 weeks		32 150 (28.7)
37 to <42 weeks		61 786 (55.1)
42 weeks or more		11 213 (10.0)
Single versus multiple gestation	115 552	
Singleton		113 424 (98.2)
Twin gestation		2092 (1.8)
Triplet or quadruplet gestation		36 (<0.1)
Timing of ruptured membranes prior to delivery	65 303	
Same calendar day		60 635 (92.9)
Earlier calendar day		4668 (7.1)
Labor induced	91 663	438 (0.5)
Mode of delivery	113 947	

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Characteristic	**No. of pregnancies with data recorded**	**Value** [a]
Spontaneous vaginal delivery		108 255 (95.0)
Cesarean delivery		4697 (4.1)
Forceps or vacuum extraction		186 (0.2)
Breech		809 (0.7)
Pregnancy outcome	115 552	
Live birth		112 813 (97.6)
Fresh stillbirth		1325 (1.1)
Macerated stillbirth		1414 (1.2)
Apgar score at 1 minute	106 524	9 (8–9)
Score <7		4416 (4.1)
Apgar score at 5 minute	103 198	9 (9–9)
Score <7		3409 (3.3)
Birth weight, g	114 572	3000 (2700–3300)
<1500 g		1622 (1.4)
1500–2499 g		10 779 (9.4)
2500–3499 g		83 314 (72.7)
3500–3999 g		16 442 (14.4)
≥4000 g		2415 (2.1)

Abbreviation: RPR, rapid plasma reagin.

[a] Values are given as number (percentage) or median (IQR) unless otherwise indicated.