The excessive use of cesarean section and its contribution factors in Shanghai, China

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Research article

Keywords: Excessive use, Cesarean section, Non-medical indications

Posted Date: November 22nd, 2019

DOI: <https://doi.org/10.21203/rs.2.17664/v1>

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Abstract

Objectives: This study proposes a mathematical analysis framework to estimate the proportion of cesarean section (CS) with non-medical indications and of CS cases correctly diagnosed, examine the excessive use of CS, and investigate its contributing factors in Shanghai.

Design and Settings A mathematical model (C-model), developed by the World Health Organization, was employed to estimate the expected proportion of women having CS based on clinical indicators. Cases in which CS occurred but vaginal delivery (VD) was recommended instead by the C-model were regarded as "Suspicious CS". Cases that are "CS of suspected non-medical indications" were identified and used for categorical principal component analysis to explore causes of "Suspicious CS". A Bayesian model was used to calculate the proportion of correctly diagnosed CS. The use of CS and medical conditions were collected from 5,686 pregnant women delivered in twenty public hospitals with obstetrics departments in 2016, which were randomly selected in Shanghai. The excessive use of CS in Shanghai and the cost of "CS suspected non-medical indications" were estimated.

Results 43.96% of pregnant women performed CS in Shanghai in 2016, much higher than the expected CS rate of 30.13% according to the C-model. A total of 1271 CS cases were classified as "Suspicious CS", representing 22.35% of the sample. There were 784 cases classified as "CS of suspected non-medical indications", including CS caused by fetal heart rate abnormality/fetal distress and cesarean delivery on maternal request (CDMR), accounting for 13.79% of the sample. Based on Bayes estimation, only 42.5% of pregnant women who had CS were medically necessary. If the CS with non-medical indications were appropriately controlled, the hospitalization costs in the whole year in Shanghai would drop by about US\$ 60 million (408 million RMB).

Conclusion The study provides empirical evidence on non-medical indications of CS in Shanghai, and uses a mathematical model to estimate the excessive use of CS. The high rate of CS in Shanghai was associated with non-medical indications. Establishing clinical standards of CS, especially in relations to abnormal fetal heart rate/fetal distress, would help reduce CS without medical indications, which would significantly lower medical expenses of hospitalization.

Background

Cesarean Section (CS) is the most commonly performed surgical operation in China.¹ The rate of CS in China has been increased from 28.8% in 2008 to 34.9% in 2014. The use of CS varied remarkably in China, ranging from 4.0% in Tibet to 62.5% in Jilin province in 2014.² In the megacities represented by Beijing and Shanghai, the rate of CS is even higher than the national average³. In 2014, it was estimated that the annual delivery in Shanghai reached 99,702, of which 52.4% used CS⁴.

The high rate of CS is evitable associated with excessive use of CS, which imposes health risk to pregnant women and children. CS, as a large operation, has more accidents and slower recovery than

vaginal birth⁵. Studies have shown that cesarean section may increase the incidence of childhood asthma, allergic dermatitis, food allergies, childhood hyperactivity and childhood obesity, and is one of the risk factors affecting children's physical and mental health⁶⁻⁸. According to recent review, it was reported that maternal mortality and maternal morbidity was higher among pregnant women with CS than those with vaginal birth⁹. CS is also associated with increased risks of some medical conditions, such as uterine rupture, abnormal placentation, stillbirth, and so on⁹. Potential health consequences from CS are still under further investigator.

Besides potential health risks to pregnant women and children, the rise of CS rate has imposed economic burden on the highly stressed health system. Corry¹⁰ found that the average hospitalization cost of CS in the United States was \$12,739 in 2010, compared with \$9,048 for natural birth. Siassakos¹¹ from UK estimated that the hospital cost of CS is 3.09 times higher than natural birth. According to a 2012–2016 survey data in Shenzhen, the hospitalization cost of cesarean section is US\$ 753 (5118.9 RMB), which is significantly higher than the US \$361 (2451.9 RMB) of natural childbirth¹². Other studies¹³⁻¹⁵ also shows that CS was associated with higher costs compared with vaginal delivery. In China, though medical and maternity insurance programs have covered the vast majority of childbirth expenditure, there was a significant difference in costs of hospitalization due to CS across provinces.¹⁶ In addition, association between CS and increased risk of adverse maternal physical conditions (e.g. placenta accreta, bladder and bowel injuries, uterine rupture) has been found,¹⁷⁻¹⁹ which further raises the medical expenditure related to CS.²⁰ With the newly released policy in China that allows two children for a couple, the costs associated with CS are expected to double or even triple in the future.

The World Health Organization emphasized that the CS should only be performed when medically necessary. However, previous studies have found that doctors' decision on CS was not only based on medical conditions, but also non-medical factors such as maternal requests or psychological tendencies of doctors, when there were no clear medical indications.^{22,23} Zhang summarized the factors contributing to the high rate of CS in China, and classified these factors into three categories: the structure of the obstetric care system, provider incentives, and patient preference. The examples of these factors include medicolegal concerns, financial incentives for physicians to perform cesareans, and parents' focus on having a "perfect baby" under the one-child policy²⁴.

In terms of the costs of CS, previous studies mainly focused on clinical complications²⁵⁻²⁷ due to CS or the costs of different delivery methods in general, without distinguishing the difference between CS due to medical indications (which is necessary) and CS without medical indications (which is not).²² One of the reasons may be that it is difficult to judge the proportion of CS caused by non-medical indications directly from the data.²⁵ Generally speaking, except for caesarean delivery on maternal request (CDMR), other CS with non-medical indications need to be performed after experts carefully reviewing medical records, which require substantial amount of clinicians' time. Thus it has been difficult to practice.

Despite high use of CS in China, there are limited studies to examine the extent of excessive use of CS, its contribution factors, and potential economic implications. To fill in this gap, this study proposes a mathematical analysis framework to separate pregnant women from CS for non-medical reasons, which are considered as excessive use. And then used to examine the potential causes of CS without medical indicators and estimate potentials economic savings.

Methods

The study used a mathematical model and statistical analyses to determine the excessive use of CS with certain groups, and estimated the proportion of CS without medical indications and of CS cases correctly performed according to their medical necessity. Then we calculated the proportion of CS cases that were excessively used, explored its contributing factors, and estimated potential savings from the reduction of excessive use of CS.

Identification of clinically necessary CS

In this study, we used C-model to determine the relationship between clinical-obstetric characteristics and CS. The C-model is a mathematical model developed by the World Health Organization (WHO)²⁸, to calculate the CS rate for medical institutions, groups of health facilities, and the probability of a woman having a CS. This model is used to generate expected proportion of CS by inputting clinical variables specified on the WHO website²⁸. The model considers the maternal demographic features and obstetrics and disease factors, including parity, previous C-section, multiple pregnancy and so on. This model has been used to predict the rate of CS, and to compare the CS rates between medical institutions at different levels, in different periods, and across different regions.²⁸ Based on the estimated probability of CS, the recommended CS rate and confidence interval are determined for each population. The uncertainty range of expected CS rate was arbitrarily defined as 20% because differences greater than 20–25% are commonly considered clinically significant or appreciable differences.²⁹ The ratio between observed and expected CS (the standardized CS ratio) was calculated and tested in the C-Model analysis. The mathematical model of C-model has been verified with the data over 10 million women from 43 countries²⁸.

At the same time, we also used the C-model to determine recommended individual probability of using CS. To verify the relationship between the aggregate expected CS rates and the individual probability of CS, all the parturient were randomly assigned to several groups. The number of parturient and the expected rates of CS in each group were recorded respectively. We found that the aggregate expected rate of CS in the sample equaled to the average probability of CS calculated from individuals. Then, we used the z-

test to determine the critical value of the probability of cesarean section to distinguish reasonable delivery methods ($P < 0.01$).

Therefore, the puerperal can be classified according to the probability of personal probability of cesarean section. When the individual probability of CS was greater than the upper limit of the total expected rate of CS, the case was considered that C-model recommends CS as delivery method. When the probability of an individual CS was less than the upper limit of the total expected rate of CS, it was recommended for vaginal delivery.

Differences were found between actual delivery and recommended methods based on the C-model probability. The cases in which women actually had CS but were not recommended by C-model were classified as “Suspicious CS” group. Those who actually had VD and were recommended with VD, and those who actually had CS and were recommended with CS were named as “Consistency” group, whereas those who had actual delivery modes of VD but were recommended with CS were named as “Advanced technique of delivery” group. Our research focused on “Suspicious CS” group, where CS can be avoided based on C-model recommendation.

Sample selection

This was a cross-sectional study that was conducted on pregnant women admitted to obstetrics departments from 20 public hospitals in Shanghai, China. In those hospitals, medical records between January 1st through June 30th, 2016 were extracted from pregnant women who had gestational duration greater than 24 weeks or who delivered with baby's weight at birth greater than 500g. The medical records captured patients' demographic and clinical information, as well as the cost of hospitalization. The selected hospitals agreed to participate in the study. All the information was kept confidentially. The study was approved by the ethics review committee of School of Medicine, Shanghai JiaoTong University and the participating hospitals.

Twenty public hospitals were randomly selected from all secondary and tertiary public hospitals that have obstetrics departments in Shanghai. A second-stage of sampling was performed by randomly selecting maternal medical records with their admission number in each hospital based on the following criteria: 10% from the hospitals having 10,000 deliveries per year or more, 20% from the hospitals having 5,000 to 10,000 deliveries per year, and 30% from the hospitals having 5,000 deliveries per year or less. In this study, there were a total of 10,855 pregnant women sampled. Samples that were not willing to provide or lacked the information on hospitalization costs were excluded (3,851 and 1,220 cases, respectively). Additionally, 98 cases were excluded due to missing or incomplete medical records. Finally, medical information of a total of 5,686 cases was collected from 20 maternity hospitals in Shanghai (Fig.1).

Variables and outcomes

In calculating the expected rate of CS and individual probability of CS, the variables entering into C-model include parity, previous CS history, multiple pregnancy, labor, presentation of babies, preterm birth, maternal age, organ dysfunction or ICU admission, placenta praevia, abruptio placentae, chronic hypertension, pre-eclampsia, renal disease, and HIV status.

For variables used in the C-model, parity had choices of “primary births”, “1-2 times” and “more than 2 times”. Previous CS was categorized into three levels: “0”, “1”, and “more than 1 time”. Labor was classified as “spontaneous labor” and “induced labor or CS before labor”. Presentation was divided into “cephalic”, “breech” and “other / transverse lie”. Preterm birth took 37 weeks as the cut-off. Maternal age is divided into “less than 20 years old”, “20-34 years old”, and “more than 34 years old”. Pre-eclampsia is divided into “no history”, “presence of pre-eclampsia” and “presence of eclampsia”. Organ dysfunction or ICU admission, placenta praevia, abruptio placentae, chronic hypertension, renal disease, HIV were dichotomous variables, and had choices only between yes or no.

To explore contribution factors on excessive use of CS and related cost, we collected the indications and total hospitalization costs from “Suspicious CS” group. In clinical practice, each CS contains at most two indications such as CDMR, scar uterus, buttock first dew/abnormal first dew, abnormal fetal heart rate/fetal distress, difficulty in labor, multiple pregnancy, amniotic fluid pollution, macrosomia, placenta previa, high blood pressure, pre-eclampsia and so on. All the above information was extracted from the medical record system of the hospitals.

Statistical analysis

A Bayesian model³⁰ were used to estimate proportion of recommended CS in Shanghai. Assuming that A is the number of women who have CS in Shanghai and B represents the number of parturient women whose modes of delivery judged by C-model is CS, according to the Bayesian model, P , where P is the probability of cases who performed CS cases and also were recommended by the C-model for CS, and can be obtained from the groups in this study.³¹ The proportion of actual CS cases were recommended by the C-model in Shanghai can be calculated, namely $P(B|A)$. According to the actual and expected modes of delivery, the conditional probability formula can be showed as Table 1.

We used what Hong-Tian Li² published about maternal delivery and rates of CS in 31 provinces and cities in China from 2008 to 2014, and estimated the rate of CS of 50.8%, which is $P(A)$, in Shanghai. Then the potential savings from controlling “Suspicious CS” were estimated according to value of $P(B|A)$ and costs of different modes of delivery, which can be calculated by the average of the total cases.

[Due to technical limitations, Table 1 could not be displayed here. Please see the supplementary files section to access the table.]

Categorical principal component analysis^{32,33} was performed to explore causes of excessive use of CS. The indicators of CS in the group of "Suspicious CS" were included in the analysis to explore the relationship between the indicators and further classify the "CS suspected non-medical indications" groups represented by CDMR.

Results

The study has surveyed 20 hospitals which have obstetrics departments in Shanghai with a total of 5686 deliveries. Table 2 shows the use of CS according to variables included in the C-model. The CS rate of multipara was higher than that of unipara. Women who had CS before is nearly three times the rate of those without CS before. Although the overall number of births in multiple pregnancy, organ dysfunction or ICU admission, placenta previa, abruptio placentae, pre-eclampsia, and HIV are relatively small, the rate of CS is relatively high, ranging from 70–100%. At the same time, premature delivery and the maternal age also have a certain impact on the rate of CS.

Table 2
The distribution of CS rate related variables in c-model

Obstetric characteristics	Variables	Total No.	CS rate, %	χ^2	P
Parity	0	3308	41.72	24.103	.000
	1–2	2200	47.91		
	> 2	178	37.08		
Previous CS	0	4779	34.04	1197.580	.000
	1	876	96.12		
	> 1	31	100		
Multiple pregnancy	singleton pregnancy	5625	43.41	65.392	.000
	multiple pregnancy	61	95.08		
labor	spontaneous labour	2821	9.36	2722.061	.000
	Induced labour / CS before labour	2865	78.04		
Presentation	cephalic	5389	44.07	2.419	.021
	breech	233	44.21		
	other / transverse lie	64	34.38		
Preterm birth	≥ 37	5386	43.67	3.701	.008
	< 37	300	49.33		
Maternal age	< 20	48	37.50	10.401	.000
	20–34	4919	43.24		
	> 34	719	49.37		
Organ dysfunction OR ICU admission	No	5684	43.95	2.550	.193
	Yes	2	100.00		
Placenta praevia	No	5594	43.48	34.038	.000
	Yes	92	73.91		
Abruptio placentae	No	5665	43.81	14.911	.000
	Yes	21	85.71		

Obstetric characteristics	Variables	Total No.	CS rate, %	χ^2	P
Chronic hypertension	No	5676	43.92	2.756	.067
	Yes	10	70.00		
Pre-eclampsia	No	5561	43.25	53.467	.000
	Pre- eclampsia	124	75.81		
	Eclampsia	1	100.00		
Renal disease	No	5677	43.93	1.885	.107
	Yes	9	66.67		
HIV	No	5665	43.76	26.862	.000
	Yes	21	100.00		

The C-model estimated that the expected CS rate was 30.13%, with the confidence intervals of 22.59–37.66%. According to the obstetrical characteristics of the maternal individuals, individual CS probability was estimated. The observed CS rate was 43.96% from the sample. We divided all the cases into four groups according to the actual and expected modes of delivery by C-Model (Table 3). We estimated that there were 1,271 CS cases that were recommended for Vaginal Delivery (VD), and 234 VD cases that were recommended for CS by the C-model.

Table 3
Case categorization based on actual and expected modes of delivery

		Expected modes of delivery		Total	χ^2	P
		VD	CS			
Actual modes of delivery	VD	2952	234	3186	1281.721	.000
	CS	1271	1229	2500		
Total		4223	1463	5686		

The result of CATPCA showed that the internal consistency coefficient of four components (Cronbach's Alpha) was 0.846. For the primary component, Cronbach's Alpha was 0.313 and yielded an eigenvalue of 1.430, accounting for 5.5% of total variance (Table 4). For the second component, Cronbach's Alpha is 0.287 with an eigenvalue of 1.382, explaining 5.316% of total variance. Based on the coefficients of component loading (Table 5), the first component was related to multiple pregnancy and premature birth and the second component was more related to CDMR and abnormal fetal heart rate/fetal distress. The third component was associated with difficulty in labor and head basin asymmetry while the fourth component was with buttock first /abnormal first. In our sample, there were 784 CS cases with fetal heart

rate abnormality/fetal distress or cesarean delivery on maternal request, which accounted for 13.79% of the sample, and of 31.36% of all CS cases.

Table 4
CATPCA Model Summary

Dimension	Cronbach's Alpha	Variance Accounted For	
		Total (Eigenvalue)	% of Variance
1	.313	1.430	5.500
2	.287	1.382	5.316
3	.247	1.312	5.046
4	.208	1.250	4.806
Total	.846	5.374	20.668

Table 5 CATPCA Component Loadings for 26 indications				
Indications	Dimension			
	1	2	3	4
CDMR	.185	.849	.080	– .260
scar uterus	.172	– .023	– .081	.276
buttock first dew/abnormal first dew	.132	– .092	– .159	.633
abnormal fetal heart rate / fetal distress	– .182	– .460	– .410	– .494
difficulty in labor	– .217	– .193	.572	– .062
multiple pregnancy	.741	– .250	.179	– .144
amniotic fluid pollution	– .095	– .195	– .210	– .335
macrosomia	– .045	.136	.060	.052
placenta previa	.003	.019	.003	– .004
Intrahepatic cholestasis in pregnancy	.110	– .104	– .144	.003
high blood pressure or pre-eclampsia	.018	– .053	– .139	.180
failure of induced labor	– .059	– .114	– .148	.015
shoulder dystocia	– .049	– .037	.185	.002
fetal malformation	– .066	– .054	.249	– .036
chorionic amnitis	.003	.019	.003	– .004
other emergencies	.243	– .095	.128	.020
HIV or herpes active lesion	– .033	– .069	– .105	– .222
head basin asymmetry	– .257	– .225	.659	.013
cord prolapse	– .033	– .064	– .019	.149
diabetes	.057	.099	– .110	.161
limitation of fetal growth	– .025	– .064	– .083	– .130
premature rupture of membranes	– .137	– .272	– .060	.345
heart disease	.012	.013	– .041	.129
premature birth	.720	– .272	.123	– .099
other fetal problems	– .111	– .144	.111	.046
other maternal problems	– .055	– .035	– .165	.158

Data from the Health Bulletin of the Shanghai Municipal Health and Family Planning Commission³⁴ showed that the number of women hospitalized for delivery in Shanghai in 2014 was 233,200, and the number of women who had CS was 118,500. Based on Bayesian theory model, we estimated that only 42.5% of CS cases were medically necessary in Shanghai, which means that the recommended number of CS deliveries in 2014 should be 50,400. The average per delivery cost of CS based on clinical data in Shanghai was US\$ 1,644 (11175.67 RMB), and the average per delivery cost of VD was US\$ 763 (5,188.95 RMB). If the unnecessary CS were controlled, the cost of hospitalization in a year would drop by US\$ 60 million (408 million RMB).

Discussion

This study explored the use of a mathematical model and statistical analyses to determine the excessive use of CS, and used the data collected from Shanghai in 2016 to demonstrate the analysis. The results showed that the rate of CS performed in Shanghai was 43.96%, greater than the upper limit suggested by the C-model by about 6.3%. There is an excessive use of CS in Shanghai. Out of a total of 5,686 women in sample, 22.4% of the sample (1,271 cases) that received CS seems more suitable for natural childbirth.

We found that the contributors of using CS mainly focused on four dimensions: CDMR, multiple pregnancy, abnormal fetal heart rate/ fetal distress and preterm birth. Among them, the multiple pregnancy and preterm birth represented by the first component is CS of high-risk. The CDMR and abnormal fetal heart rate/fetal distress represented by the second components is defined as “CS of suspected non-medical indications”, which is associated excessive use of CS. The number of CS cases classified as “CS of suspected non-medical indications” is 784, which is 13.78% of the whole sample. There is considerable evidence that CS without medical indications is associated with increased risk of maternal adverse consequences. Studies also showed that the rates of CDMR have increased dramatically in the United States and other countries. In 2004, it is estimated that 2.5% of the US births were CDMR. CDMR rates in other countries are generally reported to range from 2–16%: Rates of CDMR were 9%, 15.8%, 7.6%, and 3.5% in Italy, Sweden, Norway, and Taiwan respectively in the studies performed between 1996 and 2001.^{35,36} CDMR appears to be a considerable driver behind the increasing CS rate in mainland China. A study in 39 hospitals in 14 provinces in China showed that CDMR accounted for 15.53% of all deliveries and 28.43% of the CS deliveries.³⁷ The practice of CDMR shows a change in management of obstetrics, the increase of patients’ autonomy in deciding the mode of delivery, and mothers’ fear of episiotomies, long and painful labor associated with vaginal birth in China.^{37,38} Currently, some hospitals in Shanghai have limited the implementation of CDMR. CDMR is included in the obstetrician’s performance appraisal, thus effectively control the rates of CDMR³⁹.

Abnormal fetal heart rate/fetal distress is another contributor to the increase of CS rates, with the widespread use of electronic fetal heart monitoring. Fetal heart rate abnormality/fetal distress seems a common clinical diagnosis of CS with suspected of nonmedical indication chosen by obstetricians. A study⁴⁰ indicates that electronic fetal heart monitoring does not significantly improve the outcome of

delivery, but instead increasing the CS rate. As electronic fetal heart monitoring is sensitive to the abnormal state of the fetus but has a poor specificity, it often leads to false positive results. In addition, the judgment of electronic fetal heart monitoring is relatively subjective, so obstetricians in China might use the indications like abnormal fetal heart rate/fetal distress to perform CS, which does not affect their performance appraisal. Therefore, it is essential to provide trainings to obstetricians and gynecologists to improve the diagnosis.

Reducing unnecessary CS would yield sizable savings for the health system. We estimated that the average cost of childbirth of Shanghai in 2016 was US \$1150 (7,821.17 RMB). The cost of CS was US\$1644 (11175.67 RMB), which was 2.15 times the cost of natural childbirth (US\$ 763 [5,188.95 RMB]). Generally speaking, due to the longer average length of stay, higher cost of medical technology, more consumption of medicine and nursing, the cost of CS is significantly higher than normal childbirth. The cost is even higher for cases of CS with absolute medical indications. The National Institute for Health and Clinical Excellence guidelines⁴¹ stated that CS typically has higher costs and worse outcomes, the cases of carrying out CS due to personal and other non-medical indications may result in inappropriate use of resources in the maternity sector. Some studies showed that cesarean delivery on request has negative consequences for long-term reproductive health, including fetal wastage, abnormalities of placentation, and uterine rupture, which may affect the health and wellbeing of the woman and her future offspring.⁴² The effective way to control high health care expenditure is to reduce nonmedically indicated delivery⁴², which might cause unnecessary medical expenses and waste of medical resources. We estimated an annual savings of US\$ 60 million from unnecessary CS in 2014. As China abandons its one child policy, the savings are expected to increase substantially.

In order to control unnecessary CS, it is critical that clinicians improve their professional skills of diagnosis pregnancy complications and follow clinical guidelines of CS operations strictly. Given CDMR accounts for a large share of unnecessary CS, particular efforts should be given to change the perception of women and their families towards VD, promoting VD when CS is not necessary. According to the World Health Organization's global standards of care for healthy pregnant women in February 2018,⁴³ it is advocated to reduce unnecessary medical interventions for the best physical and emotional interest of both the mother and baby.

Some limitations of this analysis should be acknowledged. Firstly, we used the data from Shanghai, China, from 20 representative public hospitals for the analysis. We did not collect data from private hospitals in China, and thus could not provide an accurate estimate of use of CS in Shanghai. However, given the limited share of private health sector in Shanghai, we do not expect this affect the results substantially. Secondly, the C-model and CATPCA could only provide a rough estimation of recommended rate of use of CS, and help identify CS with non-medical indications. Clinical expertise is critical to make judgments on individuals' appropriateness of using CS.

Conclusion

This study provided insights in using a mathematical models and statistical analyses to determine the excessive use of CS in Shanghai and then estimate the probability of appropriate use of CS in Shanghai. The rate of CS in Shanghai is still at a high level now, and there is a certain gap between the rate of CS expected and actually performed. If the CS without medical indications is strictly controlled, the hospitalization costs in the whole year will drop by US\$ 60 million (408 million RMB) in Shanghai. Establishing clear clinical standards and guidelines for CS, especially in relations to abnormal fetal heart rate/fetal distress, are key to reducing CS without medical indications and the hospitalization costs.

Declarations

Funding This study received financial support from Major Key Research Projects in Philosophy and Social Sciences of the Ministry of Education of the People's Republic of China (Deepening the Reform of Medical and Health System in the New Era, 18JZD044) and Shanghai Municipal Commission of Health and Family Planning (GWIV-26) .

Competing Interests We have read and understood policy on declaration of interests and declare that we have no competing interests.

Patient and Public Involvement

All the information came from the medical records system was treated confidentially. The content does not cover any patient's privacy information and patients were not involved in this research.

Data Sharing Statement Data available from the Dryad Digital Repository:
<https://doi.org/10.5061/dryad.0m6f00n>

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List Of Abbreviations

Cesarean Section - CS

Vaginal Delivery – VD

Cesarean Delivery on Maternal Request – CDMR

Human Immunodeficiency Virus – HIV

Intensive Care Unit -ICU

Figures

Figure 1

The process on sample selection in this study. All the included and excluded samples has been shown.

Supplementary Files

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- [Table1.docx](#)