Prevalence and Determinants of Scheduled and Emergency Caesarean Section among Pregnant Women Admitted in Kamenge University Teaching Hospital, Burundi: a step-by-step mathematical approach

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Abstract

Background: Caesarean Section is associated with an increased risk for the mother’s health compared to natural birth worldwide and in Burundi although it is a common practice used to protect babies and mothers. Objective: This study aims to estimate prevalence of Scheduled and Emergency Caesarean Section
(SECS) among pregnant women admitted from January to December 2021 in the maternity ward of Kamenge University Teaching Hospital and examine its associated factors. **Methodology:** A sample of 362 pregnant women was randomly selected whereby data were collected from medical records. Dependent variable was scheduled/emergency caesarean section and explanatory variables were the number of abortions, twinship, place of antenatal care, age, number of pregnancies, woman’s weight and child’s height. Fisher’s exact test and logistic regression model were applied to these data using R software, version 4.1.2 to analyze respectively independence between caesarean section and each of explanatory variables and examine associated factors. **Results:** Findings showed that utmost five women out of one hundred (4.6%) underwent SECS (95% confidence interval [CI]: 2.5 – 6.9). Besides, twinship influenced significantly SECS after adjustment for woman’s weight. Probability for a woman to undergo Caesarean Section is higher among women having twins and who weigh 65 kg and over. It was lower among women not having twins and who weigh less than 65 kg. **Conclusion:** Pregnant women having twins are more likely to have SECS than their counterparts, after adjustment for their weight. This study could help public health decision-makers who are responsible for obstetrics and gynaecology to control not only maternal mortality linked to childbirth and but also child death.

**Keywords:** AUC, caesarean section, logistic regression model, Bujumbura.

1. **Introduction**

For a very long time, demographic transitions have attracted the attention of researchers, governments and nongovernmental organizations (NGOs). Population dynamics such as the change of population growth rate, the structure of age and the population distribution have an effect on national and global development challenges [10,13]. Several researchers have also devoted their works to understanding population dynamics. In fact, the British economist, Thomas Robert Malthus, has launched a debate on population issues such as indefinite population growth and its limits [7]. China’s population and other human population dynamics were analyzed and predicted using a logistic regression model [9,22]. On the other side, population growth in Indonesia and Bangladesh were analyzed using exponential and logistic model respectively [2,20]. The dynamic of the United States of America (USA) population was studied since 1790 and its mathematical representation was made [15]. Three approaches to solving the population problem according to Malthus whose debate was concentrated to demographic projection methodology and which is considered as a mathematical distribution law were described [16]. Projections of Ghana population growth were made using a mathematical model [17]. The Malthusian growth model assumes that the variation of the population at the time t is proportional to its size at this time. As a consequence, it helps to predict the population size at a near future time. The more the population increases, the more numerous the factors that disrupt its growth. These include reduction of space for
crops, decrease in agricultural production and occurrence of diseases. Hence, the logistic growth model is a corrective measure to the Malthus growth model to allow long-term predictions to be made. The logistic regression model makes it possible to get demographic projections and forecasts of the probabilities of occurrence of Caesarean Section. To our knowledge, no study has focused on modeling Scheduled and Emergency Caesarean Section (SECS) using a logistic regression and a step-by-step mathematical approach in Burundi.

Scheduled Caesarean Section may be performed in situations that prevent natural delivery such as poor positioning of the placenta or if the mother has already had a cesarean section. This Scheduled Caesarean Section may become Emergency Caesarean Section in complicated situations such as when the expected baby’s estimated weight is too high, if labor begins before the scheduled delivery date, if the mother is a potential carrier of viruses or if she is expecting twins at the first childbirth. A study conducted in Denmark used logistic and linear regressions to assess the effect of academic performance and intelligence on Caesarean Section [6]. Besides, a study carried out in Ethiopia showed that giving birth in private health facilities and having had less than four births were associated with a high risk of Caesarean Section [21]. In addition to giving birth in private hospitals, a study carried out in Vietnam showed that woman’s age, urban residence, pre-delivery body mass index (BMI), child’s birth weight, first pregnancies and gained weight during pregnancy are significantly associated with the occurrence of Caesarean Section [3]. Besides, age greater than or equal to 35, body mass index greater than or equal to 30, high child’s birth weight (3500-3999 g), secondary education level and weeks of gestation (37-38) were associated with Caesarean Section according to a records-based study conducted in Georgia [12]. Besides, women with previous history of Caesarean Section, occupation (employee), educational status (college and above) and monthly income (3000-6000 Ethiopian birrs and above) are likely to undergo Caesarean Section [18].

The purpose of this article is to estimate the prevalence of Scheduled or Emergency Caesarean Section (SECS) overall and across the socioeconomic, socio-demographic and socio-cultural characteristics of the women, examine factors influencing SECS, prioritize factors influencing SECS and predict the probabilities of undergoing Caesarean Section given other factors.

2. Materials and methods

Study area and study design: Kamenge University Teaching Hospital is located in the north of Bujumbura Municipality, the capital city of Burundi. It stands on Boulevard Mwezi Gisabo and in Ntahangwa Commune, Gihosha Zone and Muyaga Quarter. This study is cross-sectional, descriptive and analytical.

Sample size calculation: The target population is made up of 5942 pregnant women admitted and hospitalized in the Department of Obstetrics and
Gynaecology of Kamenge University Teaching Hospital from January 1 to December 31, 2019. Medical records-based data were collected from July 27 to August 26, 2022.

The sample was randomly selected and stratification was made by the month of the year. The sample size was computed as proposed by Krejcie and Morgan (1970) [19]:

\[
 n = \frac{z^2 N p (1 - p)}{d^2 (N - 1) + z^2 p (1 - p)}
\]

where \( n \) denotes the sample size, \( z \) the quintile (1.96) of the normal distribution for a probability of 0.975, \( p \) the proportion of pregnant women who underwent Scheduled or Emergency Caesarean Section (0.5), \( N \) the total number of pregnant women (5642) and \( d \) the acceptable error margin (0.05). This led to a sample size of 362 pregnant women who were admitted in the maternity ward. The pregnant women were allocated to months using a probability proportional to the size, i.e the number of pregnant women in each month.

**Study variables:** The dependent variable is binary and represents the status of a woman as having undergone Scheduled or Emergency Caesarean Section (1=Yes, 0=No). Explanatory variables were the number of abortions (0=Zero, 1=One or more), twinship (0=No, 1=Yes), place of antenatal care (0=Health center, 1=Hospital), age (years) (0=Under 35, 1=35 or more), number of pregnancies (0=0-3, 1=4 or more), women’s weight (kg) (0=Under 65, 1=65 or more) and child’s height (cm) (0=Less than or equal to 1.60, 1=more than 1.60).

**Data quality:** Because data were obtained from medical records, they were complete cases. Close categories with low expected counts were merged.

**Data analysis:** First, the prevalence of Scheduled or Emergency Caesarean Section was computed globally and across the socioeconomic, socio-demographic, socio-cultural characteristics of the women and 95% confidence intervals (CI) were used to examine the difference between prevalence rates. Second, independence between dependent variable and each explanatory variable and correlation analysis were checked using Fisher’s exact test and Pearson’s phi coefficient respectively.

Third, we developed a fixed-effect logistic regression model using a step-by-step mathematical approach. In fact, given \( y(t) \) the population at the time \( t \), then this population at a near future time \( t + \Delta t \) becomes \( y(t + \Delta t) = y(t) + \beta y(t) \Delta t \) such that dividing each member of this equation by \( \Delta t \) and tending \( \Delta t \) to zero yields to
Malthus’ equation given by the following separable differential equation [8,16,22]:

\[
\frac{dy}{dt} = \beta y
\]

(2)

where \( \beta > 0 \) denotes the population growth, i.e. the difference between births and deaths which are respectively linear increasing and decreasing functions of \( y \). The solution of the differential equation (2) is a family of curves \( y(t) = y_0e^{\beta t} \) where \( y_0 = y(0) \) is the population size at the time \( t=0 \). This solution is an exponential model where food production is unlimited and where there are no diseases. Malthus thought breaking imbalance between births and deaths should be caused by wars, epidemics or hunger. Besides, his population predictions were valid in the short term. However, population size cannot grow unlimitedly because of disasters, limited food capacity and the earth accommodation capacity \( k \).

We generated a regular sequence from 10000 to 100000 with an increment of 2000 for the vector \( y_0 \) and from 1 to 10 with an increment of 0.01 for the time \( t \). We built a loop to automate the construction of the curves for each of the 46 values of \( y_0 \) for \( \beta = 3 \) and \( \beta = -3 \) respectively. The case where the number of births is greater than the number of deaths \( (\beta > 0) \) leads to an unstable population size that tends to infinity (Figure 1). Besides, the case where the number of births is lower than the number of deaths \( (\beta < 0) \) causes the population size to tend to zero, a sign of gradual population extinction (Figure 2). The case where the number of births is equal to the number of deaths \( (\beta = 0) \) is an extreme and rare case showing a stable population.

![Figure 1: Infinite population growth](image1.png)  
![Figure 2: Population extinction](image2.png)
To correct Malthus’ model, Verhulst has proposed a non exponential model. To achieve this, he considered that the relationship between birth rate and mortality rate is negative, so that the equation (2) can be written as a differential equation with separable second member using life coefficients $\beta$ and $k$ [4,22]:

$$\frac{dy}{dt} = \beta y - ky^2 = \beta y \left(1 - \frac{ky}{\beta}\right)$$

with $c = \frac{\beta}{k}$

(3)

After some simple developments, the solution of the equation (3) is given by the logistic function:

$$y(t) = \frac{c}{l + ye^{-\beta}}$$

(4)

where $\gamma$ is a constant. The logistic function transforms the probability $p$ which takes its values in the interval $[0,1]$ to another variable that take its values in the set of real numbers using the logit link function.

Then, the multivariable logistic regression model can be written as:

$$P = \frac{e^{\beta_0 + \beta_1 X_1 + \cdots + \beta_m X_m}}{1 + e^{\beta_0 + \beta_1 X_1 + \cdots + \beta_m X_m}} = \frac{e^{X_\beta}}{1 + e^{X_\beta}} = \frac{1}{1 + e^{-X_\beta}}$$

(5)

where $p$ denotes the probability of having undergone Scheduled or Emergency Caesarean Section, $\beta_0$ the intercept, $m$ the number of explanatory variables, $\beta = \left(\beta_0, \beta_1, \beta_2, \ldots, \beta_j, \ldots, \beta_m\right)^T$ the hyper-parameter, given that the design matrix, i.e the matrix of explanatory variables is $X = \left(1, X_1, X_2, \ldots, X_j, \ldots, X_m\right)$. Box-Tidwell test was used to check if the relation between Caesarean Section and continuous explanatory variables (woman’s weight, height and age) was linear. Parameters of the model (5) were estimated using a maximum likelihood method and tested using Wald’s test at the significance level of 20% in univariate logistic regression models (one explanatory variable). The statistics of this test was drawn from a chi-square distribution with one degree of freedom. Significant variables were then introduced into the multivariable model (5) containing $r < m$ explanatory variables. A step-by-step descending selection was manually performed at the significance level of 5% using the Bayesian Information Criterion (BIC) to obtain the saturated model. This saturated model was compared to the empty model (with no explanatory variable) and the multivariable model in the sense of the BIC and the best model was the one with a small BIC value. Wald’s test was also used to check the significance of the overall model. The null hypothesis says that all parameters are equal to zero, to mean that there is no independent variable that explains the model. The difference between the null deviance (deviance of the
null or empty model) and the residual deviance (deviance of the current model) and their degrees of freedom were computed. The p-value of this test is complementary of the probability that this difference is equal to or greater than the theoretical chi-square statistics. To check if the saturated model was well specified, the link test was used. The null hypothesis of this test was not rejected if the p-value corresponding to the added squared term was equal to or greater than 0.05. To measure gross effect and net effect of each explanatory variable, non adjusted odds ratios (OR) and adjusted odds ratios (aOR) and their 95% confidence intervals were reported. The contribution of different variables to the explanation of the Scheduled or Emergency Caesarean Section was computed as the difference between the chi-square of the saturated model and the chi-square of the saturated model without the variable divided by the chi-square of the saturated model.

The Receiver Operator Characteristic (ROC) curve plots the true positive rate (Sensitivity) on y axis against the false positive rate (1-Specificity) on x axis. It was used to diagnose the ability of the saturated model to classify caesarean and not caesarean women. The area under curve (AUC), a measure of predictive accuracy, was estimated. If AUC=0.5, there is no discrimination. This discrimination is qualified as insufficient for 0.5<AUC<0.7, acceptable for 0.7≤AUC<0.8, excellent for 0.8≤AUC<0.9, exceptional for AUC ≥ 0.9 and perfect for AUC=1. Probability of being caesarean for a given woman and according to selected explanatory variables was computed if the discrimination is at least acceptable. Data were analyzed using R software, version 4.1.2.

3. Results

At the threshold of 5%, the Box-Tidwell test does not reject the null hypothesis of non-linearity between occurrence of Caesarean Section and woman’s weight (p-value=0.229), height (p-value=0.810) and age (p-value=0.317). The woman's weight is non-linear and will therefore be introduced into the logistic model in its discrete form. Of 362 women, 17 underwent Caesarean Section, giving an overall prevalence of 4.6% (95% Confidence Interval [CI]: 2.5 – 6.9) (Table 1).

In addition, the highest prevalence of Caesarean Section (26.7%, CI: 2.2 – 51.2) was found among women who had twins. On the other hand, the lowest prevalence of Caesarean Section (2.9%, CI: 0.6 – 5.2) was observed among women whose weight was less than 65 kg. Fisher’s exact test rejects the null hypothesis of independence between Caesarean Section and only twinship (Odds ratio [OR]: 9.20, 95% CI: 1.89 – 36.99, p-value=0.003). Based on Pearson’s phi coefficient, there is a significant association between these two variables (phi: 0.216, p-value<0.001). At a significance level of 20%, twinship (p-value=0.001), number of pregnancies (p-value=0.098), mother’s weight (p-value=0.070) and child’s height (p-value=0.110) were significant associated with Caesarean Section in univariate models.
Table 1: Characteristics of women

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Categories</th>
<th>Total</th>
<th>Cesarean %</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of abortions</td>
<td>Zero</td>
<td>311</td>
<td>13</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>One or more</td>
<td>51</td>
<td>4</td>
<td>7.8</td>
</tr>
<tr>
<td>Twinship</td>
<td>Yes</td>
<td>15</td>
<td>4</td>
<td>26.7</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>347</td>
<td>13</td>
<td>3.7</td>
</tr>
<tr>
<td>Place of antenatal care</td>
<td>Health center</td>
<td>243</td>
<td>10</td>
<td>4.1</td>
</tr>
<tr>
<td></td>
<td>Hospital</td>
<td>119</td>
<td>7</td>
<td>5.9</td>
</tr>
<tr>
<td>Age class (years)</td>
<td>&lt;35</td>
<td>306</td>
<td>13</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>35+</td>
<td>56</td>
<td>4</td>
<td>7.1</td>
</tr>
<tr>
<td>Pregnancy</td>
<td>0-3</td>
<td>275</td>
<td>10</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>4+</td>
<td>87</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Women’s weight (kg)</td>
<td>&lt;65</td>
<td>207</td>
<td>6</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>≥65</td>
<td>155</td>
<td>11</td>
<td>7.1</td>
</tr>
<tr>
<td>Child’s height (cm)</td>
<td>≤1,60</td>
<td>237</td>
<td>8</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>&gt;1,60</td>
<td>125</td>
<td>9</td>
<td>7.2</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td>362</td>
<td>17</td>
<td>4.6</td>
</tr>
</tbody>
</table>

The multivariable logistic model (Table 2) (BIC=143.07) containing significant variables in univariates models was better than the empty model (BIC=150.37).

Table 2 : Multivariable logistic regression model

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Categories</th>
<th>aOR</th>
<th>95% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twinship</td>
<td>No</td>
<td>1.00</td>
<td>9.54</td>
<td>2.29 – 35.36</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>9.54</td>
<td>95% CI</td>
<td>0.001</td>
</tr>
<tr>
<td>Number of pregnancies</td>
<td>0-3</td>
<td>1.00</td>
<td>1.00</td>
<td>0.290</td>
</tr>
<tr>
<td></td>
<td>4+</td>
<td>1.75</td>
<td>0.59 – 4.91</td>
<td>0.290</td>
</tr>
<tr>
<td>Woman’s weight (kg)</td>
<td>&lt;65</td>
<td>1.00</td>
<td>1.00</td>
<td>0.076</td>
</tr>
<tr>
<td></td>
<td>≥65</td>
<td>2.61</td>
<td>0.93 – 8.07</td>
<td>0.076</td>
</tr>
<tr>
<td>Child’s height (cm)</td>
<td>≤1,60</td>
<td>1.00</td>
<td>1.00</td>
<td>0.122</td>
</tr>
<tr>
<td></td>
<td>&gt;1,60</td>
<td>1.24</td>
<td>0.80 – 6.34</td>
<td>0.122</td>
</tr>
</tbody>
</table>

Number of pregnancies (BIC=145.55) and child’s height (BIC=142.14) were sequentially removed from the full model. At a significance level of 5%, twinship significantly influences Caesarean Section after adjustment for woman’s weight (Table 3). Their contributions to the chi-square without the variable in terms of proportions are 72.73% and 1.65% respectively.
Table 3: Saturated logistic regression model

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Categories</th>
<th>aOR</th>
<th>95% CI</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Twinship</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>10.24</td>
<td>2.51 – 36.65</td>
<td>0.0005</td>
<td></td>
</tr>
<tr>
<td>Woman’s weight (kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;65</td>
<td>1.00</td>
<td></td>
<td></td>
<td>0.057</td>
</tr>
<tr>
<td>≥65</td>
<td>2.77</td>
<td>0.999 – 8.49</td>
<td>0.057</td>
<td></td>
</tr>
</tbody>
</table>

Women carrying two babies are 10.24 times more likely to undergo a Caesarean Section than women carrying one baby after adjustment on women’s weight. The link test as a goodness-of-fit test does not reject the null hypothesis that the saturated model adequately fits the data (z=1.40, p-value=0.162). So, the model is valid, showing that predicted probabilities of undergoing Caesarean Section are close to the observed ones. Furthermore, Pearson chi-square adequacy test strongly rejects the null hypothesis which says that the saturated model is not adequate ($\chi^2=14.4$, df=2, p-value=0.0008), to mean that there is at least one variable that explains the model. For both selected variables (twinship and woman’s weight), the contribution to the chi-square was 12.1.

The area under the ROC curve, the predictive power of the reduced fitted model, is equal to 0.73 (Figure 2). Discrimination is therefore acceptable. Hence, prediction of the probabilities of undergoing Caesarean Section can be made.

![ROC curve and area under curve](image)

**Figure 2:** ROC curve and area under curve

The contribution to the chi-square without the variable was 3.3 (72.72%) and 11.9 (1.65%) respectively, showing that twinship contributes more to the chi-square than the child’s weight. Moreover, a twinned woman weighing 65 kg or more has
a probability of 0.38 of undergoing Caesarean Section while the probability of undergoing Caesarean Section is 0.02 for a non-twinned woman weighing less than 65 kg. Only 3.59% (13/362) of observations have a high studentized residual (Figure 3) and only 6.08% (22/362) of observations have a high Cook’s distance (Figure 4).

The reduced or saturated model is written as follows:

\[
\logit(p) = -3.80 + 2.33 \times \text{Twinship (Yes)} + 1.02 \times \text{Weight} (\geq 65) + \varepsilon
\]  

(6)

where \( p \) represents the probability of undergoing Caesarean Section, Twinship stands for the case where the woman is carrying twins and Weight is the woman’s weight and \( \varepsilon \) an error term.

4. Discussion

In this study, the prevalence of Emergency or Scheduled Caesarean Section was estimated at 4.6% (95% CI: 2.5 – 6.9). The Burundi Demographic and Health Survey conducted in 2016-2017 reported a prevalence of 5% (CI: 4.6 – 5.4), 2.1% (CI: 1.9 – 2.3) and 2.9% (CI: 2.6 – 3.2) for Caesarean Section, Scheduled Caesarean Section and Emergency Caesarean Section respectively [11]. This little discrepancy (4.6% versus 5%) is due to the fact that our study was carried out in a hospital where prevalence of Caesarean Section is high, but the difference is not significantly different. The prevalence of Emergency or Scheduled Caesarean Section (4.6%) was lower than that recommended by World Health Organization (10% – 15%). Besides, this prevalence is extremely lower than those (24% and 10.65%) found in a study conducted in Kampala International University and Lubumbashi hospitals [5,14]. Findings showed that women’s twinship is significantly associated with Scheduled or Emergency Caesarean Section after
adjustment for her weight. Twins gestations (multiple pregnancies) expose the woman to potential obstetric complications [1]. In some cases, these complications are not favorable to the mother and/or the child for vaginal delivery. Hence, Caesarean Section can be carried out either emergently or scheduled and may affect maternal health especially when it is not well done. The planned or scheduled Caesarean Section may be offered if difficulties in the course of childbirth are foreseeable and likely to have consequences for the baby and/or the mother. Our findings corroborate those found in a study conducted in urban settings of Vietnam and which showed that the risk of Caesarean Section is higher amongst women with pre-pregnancy high weight or body mass index [3].

Normally, the causes of Scheduled Caesarean Section are so multiple and linked to the condition of the parturient or the fetus. This may be due to the maternal pelvis which does not allow vaginal delivery, the uterus to be scarred several times and fetal macrosomia, i.e. large baby in terms of weight. Emergency Caesarean Section, as for it, is particularly due to pre-eclampsia (hypertension, edema and presence of proteins in the urine), premature detachment of the normally inserted placenta or retroplacental hematoma, prolonged labor (more than 24 hours), placenta preavia, cord prolapse and fetal distress. Like any surgical procedure, Caesarean Section can exceptionally have disadvantages. This may include local pain at the injection site and damage to organs near the uterus. It would be better to insist on increasing the number of antenatal care (ANC) sessions for pregnant women and for primigravidas and multigravidas, especially in the third trimester, in order to be able to evaluate the prognostic factors for childbirth.

4. Conclusion

This study shows that at least five women out of one hundred underwent Scheduled or Emergency Caesarean Section in 2021. It shows also that women’s twinship influences significantly Scheduled or Emergency Caesarean Section after adjustment for weight. Besides, probability for a woman to be caesarean was higher amongst women whose weight is 65 kg and above and having twins whereas it was lower amongst women weighting less than 65 kg and not having twins. This study could help public health decision-makers involved with maternal health in their responsibilities to identify interventions to prioritize.

Acknowledgements. The authors are thankful to the Director of Kamenge University Teaching Hospital for providing access to data.
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https://doi.org/10.21276/sjpmms.2018.5.5.4


Received: March 3, 2024; Published: June 12, 2024