Applying the Robson classification to routine facility data to understand the Caesarean section practice in conflict settings of South Kivu, eastern DR Congo

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Abstract

Introduction
Sub-Saharan Africa has low Caesarean (CS) levels, despite a global increase in CS use. In conflict settings, the pattern of CS use is unclear because of scanty data. We aimed to examine the opportunity of using routine facility data to describe the CS use in conflict settings.

Methods
We conducted a facility-based cross-sectional study in 8 health zones (HZ) of South Kivu province in eastern DR Congo. We reviewed patient hospital records, maternity registers and operative protocol books, from January to December 2018. Data on direct conflict fatalities were obtained from the Uppsala Conflict Data Program. Based on conflict intensity and chronicity (expressed as a 6-year cumulative conflict death rate), HZ were classified as unstable (higher conflict death rate), intermediate and stable (lower conflict death rate). To describe the Caesarean section practice, we used the Robson classification system. Based on parity, history of previous CS, onset of labour, foetal lie and presentation, number of neonates and gestational age, the Robson classification categorises deliveries into 10 mutually
exclusive groups. We performed a descriptive analysis of the relative contribution of each Robson group to the overall CS rate in the conflict stratum.

**Results**

Among the 29,600 deliveries reported by health facilities, 5,520 (18.6%) were by CS; 5,325 (96.5%) records were reviewed, of which 2,883 (54.1%) could be classified. The overall estimated population CS rate was 6.9%. The proportion of health facility deliveries that occurred in secondary hospitals was much smaller in unstable health zones (22.4%) than in intermediate (40.25) or stable health zones (43.0%). Robson groups 5 (previous CS, single cephalic, ≥ 37 weeks), 1 (nulliparous, single cephalic, ≥ 37 weeks, spontaneous labour) and 3 (multiparous, no previous CS, single cephalic, ≥ 37 weeks, spontaneous labour) were the leading contributors to the overall CS rate; and represented 75% of all CS deliveries. In unstable zones, previous CS (27.1%) and abnormal position of the fetus (breech, transverse lie, 3.3%) were much less frequent than in unstable and intermediate (44.3% and 6.0% respectively) and stable (46.7%and 6.2% respectively). Premature delivery and multiple pregnancy were more prominent Robson groups in unstable zones.

**Conclusion**

In South Kivu province, conflict exposure is linked with an uneven estimated CS rate at HZ level with at high-risks women in conflict affected settings likely to have lower access to CS compared to low-risk mothers in stable health zones.

**Background**

It is commonly heralded that a caesarean section (CS) rate between 10–15% is associated with public health benefits for mothers and new-borns [1, 2]. Globally, there is a growing recognition of CS as an emergency and essential surgical care, thus a key component of universal health coverage. The World Health Organisation (WHO) statement on CS rate [3] and the Lancet commission on global surgery [4] have all renewed the pressing call for investment in obstetric surgery and provision of CS to all women in need. However, unlike in many middle and high income settings where the CS rate has excessively increased beyond what is believed adequate, sub-Saharan Africa remains a region with the lowest and suboptimal CS levels [5, 6]. The 2018 Lancet series on CS reported a 14-fold higher use of CS in the Dominican Republic (58%) compared to the average of 4.1% observed in west and central African countries of which the Democratic Republic of Congo (DRC) is part [7]. In addition to the low rate, low-income settings bear a disproportionately high burden of perinatal complications of CS [8]. A recent study reported a 50-fold higher maternal mortality associated with delivery by CS in Africa compared to high income countries [9].

In conflict and post-conflict regions of Africa, populations are impoverished and illiterate [10], fertility rates high [11, 12] and there is often an inextricable coexistence of (lack of clear) governments agendas [13], faith-based actors and humanitarian donors’ actions with sometimes diverging priorities [14], as it is the case in eastern DRC [15]. The conflict in the Kivu region (DRC) has lasted for decades and has had destructive direct and indirect health effects [16–18]. Though the war in DRC officially ended in 2002 [19], there were about 140 active armed groups still operating in the Kivu in 2019 [20]. In such a context of protracted conflict,
the blurred landscape of the CS use and its outcomes is compelling and requires a special attention.

The 2018 DRC Multiple Indicator and Cluster Survey (MICS) estimated the CS rate at 4.7% nationwide; the Kivu region had noticeably higher CS rates (12.3% in North Kivu and 10.8% in South Kivu) [21]. Higher coverage rates were also reported for other interventions indicators in the reproductive, maternal, new-born and child health (RMNCH) continuum [22]. But whether and to which extent the protracted Kivu conflict has influenced the use of CS across and within health zones of the Kivu provinces is yet to be fully assessed.

A recent nationwide survey suggested that only 2.9% of health facilities provided comprehensive emergency obstetric care (CEmOC) in DRC, moreover, of low quality [22]. In this study, we aimed to describe the patterns of CS rate vis-à-vis exposure to armed conflict, by applying the Robson classification system [23] to routine data from secondary health facilities in South Kivu. Our ultimate goal is to inform strategies towards a universal and optimal access to CS for the women most in need in eastern DRC and other similar fragile contexts.

Methods
Study design, settings and population
We conducted a facility-based cross-sectional study in 8 of the 34 health zones (HZ) of South Kivu, covering 27.6% of the estimated 6,937,726 inhabitants of this province in 2018, based on population projections from the South Kivu provincial health division. The selection of the study sites was based on a priori geographical (rural versus urban, accessible versus hard-to-reach health zones), security and health systems criteria (reported levels of CS and presence of humanitarian actors). Bunyakiri, Fizi, Idjwi, Kadutu, Kalehe, Mulungu, Mwana and Walungu health zones were selected. Fizi HZ has long remained a hotspot of conflict and insecurity [24], and is the focus of substantive humanitarian action [25]. Mulungu HZ is also armed groups-prone and one of the hardest-to-reach HZ of South Kivu, but has a relatively weak presence of humanitarian actors as opposed to Fizi. Idwi HZ is the largest island of the Kivu Lake and has been relatively spared from direct effects of the decades-long eastern DRC conflict. Kadutu is a semi-urban health zone located in Bukavu, the capital city of South Kivu. Bunyakiri, Kalehe, Mwana and Walungu are rural HZ recovering from conflict with varying presence of internally displaced persons and humanitarian actors subsidizing C-section services [25].

Definition of exposure to armed conflict. The Uppsala Conflict Data Program Georeferenced Events Dataset (UCDP GED) was the main source of conflict exposure data. Georeferenced conflict events and deaths data were merged with the shape files of the 516 DRC health zones obtained from the United Nations Office for Coordination of Humanitarian Affairs (UNOCHA) with the use the of QGIS 3.4 software. For each of the eight health zones included in this study, the number of total deaths directly attributable to conflict was used to calculate a cumulative death rate. In fact, the number of total fatalities recorded in 2018 and the five previous years was divided by the average annual population estimate to capture the intensity and chronicity of conflict. Fizi and Mulungu health zones had a cumulative conflict death rate of 51.7 and 21.0 per 100,000 inhabitants and were classified as unstable or insecure. Bunyakiri and Kalehe had a death rate of 2.4 and 8.3 per 100,000 and were considered intermediate. All the other HZ had a death rate of 0.4 per 100,000 or lower and were treated as stable or least insecure.

Within each health zones, secondary health facilities that officially offered C-section services throughout 2018 were targeted. In Kadutu health zone, data collectors were denied access to hospital records in one health facility affiliated with a public university. Two more health
facilities were not accessible because of active conflict in Fizi and completely impassable forested roads in Mulungu.

The study population under this study is comprised of women who delivered by Caesarean section in 2018, based on health facility records from health facilities in these 8 health zones.

**Data collection and the Robson classification.** A structured questionnaire was used by 8 data collectors who were all medical doctors trained on the use of the Robson classification system. The latter was first proposed in 2001 as a method for assessing the CS rate among women with various obstetrical characteristics [26]. It has proved to be an objective and standardised tool for monitoring, auditing, and comparison of CS rate trends across institutions, regions and over time [27–31]. Records review included patient hospital records, maternity and operating rooms registers and protocol books, from January to December 2018. Data were sought for sociodemographic characteristics, obstetrical history of mothers who delivered by CS and new-borns characteristics. Data collectors were assigned to classify women with sufficient information into the 10 Robson groups. The classification work was then cross-checked, corrected with Microsoft excel and validated by a supervisor who was also a medical doctor. The WHO has declared the Robson classification a standardized tool for analysing trends in CS rates within and between health facilities globally [3]. Based on parity, history of previous CS, onset of labour, foetal lie and presentation, number of neonates and gestational age, the Robson classification categorises deliveries into 10 mutually exclusive groups.

**Analysis of CS practise using the Robson classification.** The main study outcome was the relative contribution of each Robson group to the overall CS delivery rate, expressed as the number of women with a CS delivery in a group divided by the total number of CS that could be correctly classified. The secondary outcome was the estimated population CS rate. Pearson’s chi squared test was used to compare the sociodemographic and healthcare characteristics of mothers and new-borns. We used the 10-group Robson classification to describe the Caesarean section practice [26]. For each Robson class, we report the relative contribution on the overall CS rate in terms of the number of CS in the group over the total number of CS in the conflict category.

**Estimating the population CS rate.** We applied the crude birth rate (CBR) reported in the latest 2018 DRC MICS (46.0 and 37.5 live births for 1000 population in rural and urban areas respectively) to the 2018 population projections from the South Kivu Ministry of Health to estimate the population CS rate. The 2018 DRC MICS also estimated the health facility delivery proportion at 93.5% in South Kivu [21]. The numerators for CS rates estimates were CS counts from studied secondary-level health facilities and the online District Health Information System (DHIS2) at health zone level. We report CS rate estimates using both CS count data collected from secondary level health facilities and HZ data available in the DHIS2 to account for under or over reporting. The alpha error margin was set to p<0.05. Analyses were done with Stata 15.

**Ethical consideration**

The protocol of this non-human subject study was approved by the ethics committee of the Université Catholique de Bukavu. Permission to access facility records was obtained from the South Kivu Ministry of Health (MoH) and health facilities officials.

**Results**

Thirty secondary health facilities were successfully investigated, of which 11 were fully government-owned, 14 were run by faith organisations and 5 were private. From these facilities, 5520 CS (18.6%) out of 29,600 deliveries were reported, of which 5325 records were available, corresponding to 96.4% of the CS deliveries and 18.0% of all the deliveries recorded.
General characteristics mothers and new-borns

Table 1 displays the socio-demographic and healthcare characteristics of mothers and new-borns. Fourteen percent of the study population were adolescents and this proportion tended to increase with the level of insecurity (p<0.001). While 16.9% of the study population had a history of at least one abortion, 27.7% were nulliparous and 22.1% had a history of at least one death in the offspring; the proportion of mothers with at least two deaths in the offspring in unstable HZ was over double (12%) than that in stable HZ (5.9%). A history of previous CS was common in 55.8% percent of the study population with an inverse downward trend along the conflict gradient. In unstable HZ, the level of preterm births (13.7%) was 2.4-fold and 4.5-fold higher than that in intermediate and stable health zones respectively (p<0.001). Likewise, low birth weight in unstable HZ (15.3%) was 1.9 and 1.8 times more common than in intermediate and stable HZ respectively (p<0.001). Only 20.8% of women reported having a

| Variable                              | Total       | Stable       | Intermediate | Unstable    | P value |
|---------------------------------------|-------------|--------------|--------------|-------------|---------|
| Maternal age (year), n = 4823         |             |              |              |             |         |
| <20                                   | 676 (14.0)  | 284 (10.1)   | 246 (18.4)   | 146 (21.8)  |         |
| 20–34                                 | 3520 (73.0)| 2151 (76.4)  | 918 (68.8)   | 451 (67.2)  |         |
| 35+                                   | 627 (13.0)  | 382 (13.5)   | 171 (12.8)   | 74 (11.0)   | <0.001  |
| Abortion, n = 3420                    |             |              |              |             | 0.002   |
| 0                                     | 2842 (83.1)| 1513 (83.4)  | 840 (84.3)   | 489 (80.3)  |         |
| 1                                     | 421 (12.3)  | 204 (11.3)   | 116 (11.6)   | 101 (16.6)  |         |
| 2+                                    | 157 (4.6)   | 97 (5.4)     | 41 (4.1)     | 19 (3.1)    |         |
| Parity, n = 3673                      |             |              |              |             | <0.001  |
| 0                                     | 1018 (27.7)| 585 (28.9)   | 235 (23.4)   | 198 (30.9)  |         |
| 1                                     | 599 (16.3)  | 348 (17.2)   | 132 (13.1)   | 119 (18.6)  |         |
| 2+                                    | 2055 (56.0)| 1092 (53.9)  | 639 (63.5)   | 324 (50.6)  |         |
| Previous C-section, n = 4,065         |             |              |              |             | <0.001  |
| No                                    | 1798 (44.2)| 887 (40.3)   | 646 (47.6)   | 265 (52.7)  |         |
| Yes                                   | 2267 (55.8)| 1317 (59.8)  | 712 (52.4)   | 238 (47.3)  |         |
| Gestational age (weeks), n = 3273     |             |              |              |             | <0.001  |
| <37                                   | 168 (5.1)   | 57 (3.0)     | 56 (5.7)     | 55 (13.7)   |         |
| 37–38                                 | 1015 (31.0)| 486 (25.9)   | 383 (38.7)   | 146 (36.2)  |         |
| 39–41                                 | 1879 (57.4)| 1229 (65.4)  | 467 (47.1)   | 183 (45.4)  |         |
| 42+                                   | 211 (6.5)   | 107 (5.7)    | 85 (8.6)     | 19 (4.7)    |         |
| Birth weight, n = 4748                |             |              |              |             | <0.001  |
| <2500                                 | 446 (9.4)   | 240 (8.7)    | 108 (8.1)    | 98 (15.3)   |         |
| 2500–2999                             | 1151 (24.2)| 637 (23.0)   | 279 (21.0)   | 235 (36.0)  |         |
| 3000–3999                             | 2755 (58.0)| 1647 (59.5)  | 814 (61.3)   | 294 (45.1)  |         |
| 4000+                                 | 396 (8.3)   | 244 (8.8)    | 127 (9.6)    | 25 (3.8)    |         |
| Death history in the offspring, n = 3404|          |              |              |             | <0.001  |
| Zero                                  | 2651 (77.9)| 1510 (84.1)  | 726 (73.0)   | 415 (67.7)  |         |
| One                                   | 453 (13.3)  | 181 (10.1)   | 150 (15.1)   | 122 (19.9)  |         |
| Two or more                           | 300 (8.8)   | 105 (5.9)    | 119 (12.0)   | 76 (12.4)   |         |
| Health coverage, n = 1929             |             |              |              |             | <0.001  |
| No                                    | 1528 (79.2)| 975 (94.2)   | 439 (90.7)   | 114 (27.8)  |         |
| Health coverage                       | 401 (20.8)  | 60 (5.8)     | 45 (9.3)     | 296 (72.2)  |         |

Data are n (%). The sample size varies between variables depending on the completeness of data sources.

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health coverage among those with available data (n = 1929), and this number was remarkably higher (p < 0.001) in unstable HZ (72.2%) than in intermediate (9.3%) and stable ones (5.8%).

Description of the CS practice using the Robson classification

We assumed that the all health zones had the same institutional delivery rate to obtain the estimated number of deliveries in the population. Based on this denominator, the distribution of C-section based on the Robson classification is presented by conflict location in Table 2. Of the 5235 CS recorded and reviewed, 2883 (54.1%) could be correctly classified. Overall, Robson groups 5 (44.1%), 1 (19.7%) and 3 (14.7%) were the leading single contributors to the overall CS rate and altogether represented 75% of all CS. The contribution of group 1 appeared identical across conflict locations whereas group 3 seemed to contribute more to overall CS rate in unstable (19.8%) and intermediate (19.4%) than in stable HZ (11.4%). Remarkably, 46.7% and 44.3% of CS in stable and intermediate HZ respectively concerned the Robson group 4 (Multiparous with previous Caesarean section, singleton, cephalic, ≥37 weeks’ gestation) while this group contributed only 27.1% of the CS rate in unstable HZ. Robson group 10 (preterm births) accounted for up to 13.2% of the CS rate in unstable HZ against only 2% in stable HZ and 5% in intermediate HZ.

The unstable health zones have much lower proportion of institutional deliveries taking place in secondary health facilities with CS capacity: 22.4% of all facility deliveries compared to 40.2% and 43.0% in intermediate and stable health zones respectively.

Description and comparison of CS levels by conflict location

We assumed that the all health zones had the same institutional delivery rate to obtain the estimated number of deliveries in the population. Based on this denominator, the estimated CS rate at population level was 6.9% in the 8 health zones of study. Unstable health zones had markedly lower CS levels (4.1%) than intermediate (8.6%) and stable zones (7.6%). In fact, the estimated population CS rate in unstable zones appeared almost half that in intermediate zones and stable health zones. The health facility CS rate ranged from 12.4% in Idjwi (a stable health zone) to 32.9% in Mulungu (unstable health zone) (Table 3). However, Idjwi (island) and Mulungu health zone (the remotest), despite having a different security history, appeared
to have the lowest population CS rates. The unstable health zones have much lower proportion of institutional deliveries taking place in secondary health facilities with CS capacity: 22.4% of all facility deliveries compared to 40.2% and 43.0% in intermediate and stable health zones respectively.

Missing data pattern

The pattern of missing data was uneven across variables (Table 4). Of the core Robson system variables, gestational age was the most concerned by missing data (38.5%) while the number of foetuses was the most reported parameter with 11.6% of missing data.

Discussion

In this facility-based cross-sectional study, overall, the estimated population CS rate was 6.9% and appeared higher in intermediate health zones compared to stable and unstable locations. The proportions of adolescent mothers, preterm births, new-borns with low birth weight and mothers with history of deaths in the offspring appeared significantly higher in unstable locations. The Robson group 5 was relatively the largest single contributor to the CS rate in all the three conflict contexts.

A number of patterns in our data indicate a differential use of CS based on whether a woman lives in conflict-affected HZ or not. The level of CS use observed in this study appeared lower than the South Kivu average estimated at 10.8%, but higher than the national average (4.1%) [32]. This finding can be explained by lower availability and limited access to CS and other CEmOC services in conflict-affected or rural settings representing the majority of the

| Health zones | 2018 Population | Estimated births in HZ | Estimated health facility births | SHF deliveries | SHF CS | Population CS |
|--------------|-----------------|------------------------|---------------------------------|----------------|--------|----------------|
|              |                 |                        |                                 |                |        | With DHIS2 numerator | With SHF numerator |
| Stable       | 1060620         | 45645                  | 42679                           | 18347          | 3272   | (17.8)*       | 3057 (7.1)       | 7.6% |
| Idjwi        | 281983          | 12971                  | 12128                           | 3411           | 424    | (12.4)       | 380 (3.2)       | 3.5% |
| Kadutu       | 369712          | 13864                  | 12963                           | 7382           | 1245   | (16.9)*       | 1136 (8.2)      | 9.0% |
| Mwana        | 139332          | 6409                   | 5993                            | 3323           | 862    | (25.9)       | 731 (12.3)      | 14.6% |
| Walungu      | 269593          | 12401                  | 11595                           | 4231           | 741    | (17.5)       | 810 (7.1)       | 6.5% |
| Intermediate | 392878          | 18072                  | 16898                           | 6797           | 1438   | (21.2)       | 1386 (8.3)      | 8.6% |
| Bunyakiri    | 212083          | 9756                   | 9122                            | 2913           | 772    | (26.5)       | 898 (10.0)      | 8.6% |
| Kalehe       | 180795          | 8317                   | 7776                            | 3884           | 666    | (17.1)       | 488 (6.4)       | 8.7% |
| Unstable     | 462906          | 21294                  | 19910                           | 4456           | 810    | (18.2)       | 1044 (5.3)      | 4.1% |
| Fizi         | 310755          | 14295                  | 13366                           | 3681           | 555    | (15.1)*      | 789 (6.0)       | 4.2% |
| Mulungu      | 152151          | 6999                   | 6544                            | 775            | 255    | (32.9)*      | 255 (3.9)       | 3.9% |
| Total        | 1916404         | 85012                  | 79486                           | 29600          | 5520   | (18.6)*      | 5487 (6.9)      | 6.9% |

SHF: secondary-level health facility. Data are n and n (%), unless otherwise specified. *: The number of CS deliveries performed in the 3 health facilities that could not be accessed were obtained from the DHIS2 to allow more accurate estimates (104 in Kadutu, 8 in Fizi and 85 in Mulungu). Data are n and n (%), unless otherwise specified. Secondary-level health facilities (SHF) are those that have a permanent medical doctor, and can officially offer hospitalization and CS services. The crude birth rate (CBR) reported in the latest (2018) DRC MICS (46.0 and 37.5 live births for 1000 population in rural and urban areas respectively) was applied to the 2018 population projections from the South Kivu Ministry of Health. The 2018 DRC MICS also estimated the health facility delivery proportion at 93.5% in South Kivu. The numerators for CS rates estimates were CS counts from studied SHF and the online District Health Information System (DHIS2) at health zone level.

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health zones included in this study. Higher CS use level in conflict and post-conflict health zones than the national average (5.1%) indicates that other health systems factors than conflict play a critical role [21, 33]. The lower CS use observed in unstable areas could reflect the lack of healthcare facilities and the poor access to health services. The higher CS rate in intermediate zones may be partly explained by the strong presence of humanitarian actors in these locations on the one hand [34], and a lower intensity of conflict compared to unstable locations on the other. The presence of humanitarian action may result in better funding of the local health system, and better retention rate of qualified health workers, reporting and quality data keeping, and maternal and child health coverage indicators respectively. Lastly, the lower CS rate in unstable HZ may allow some women to avoid the high morbidity and mortality risk associated with CS in low-income countries [9].

Of note was also the larger size of Robson group 10 (preterm deliveries) in unstable HZ, in line with worse mothers and new-borns health characteristics observed in conflict locations, notably adolescent expecting mothers, low birth weight and preterm babies and deaths in mothers’ offspring. This trend would have even been more marked if data incompleteness on gestational age was not higher in unstable locations compared to stable ones. One of the rare studies focusing on pregnancy outcomes in eastern DRC pointed to a two-fold increase in the rate of preterm births in a hospital following the eruption of the 1997 war in the now Ituri province [35], consistent with the literature from other conflict-plagued contexts [36]. Inaccurate estimation of gestational age, mostly based on clinical evaluations and last menstrual periods is possible [37], though the latter was suggested to be a reliable alternative for the assessment of gestational age in low-income settings where early pregnancy ultrasound is not readily accessible [38].

The size of Robson group 8 appeared larger than the expected number of multiple pregnancies in the general population [39]. This finding is in agreement with the high level of preterm births observed in health facilities surveyed, given the high likelihood of preterm deliveries in women with multiple pregnancies. This result may also be indicative of doctors’ conservative propensity vis-à-vis CS in mothers with twin pregnancies in resource-constrained settings where maternal and child mortality and morbidity associated to multiple pregnancy delivery is high [40]. This result could also indicate a likely high twinning rate in South Kivu; further studies are needed to support this hypothesis.

### Table 4. Distribution of missing data by crisis location.

| Variable                  | Stable | Intermediate | Unstable | Total     | P value |
|---------------------------|--------|--------------|----------|-----------|---------|
| Robson                    | 1452 (45.3) | 544 (37.8)   | 446 (62.0) | 2442 (45.9) | <0.001  |
| Maternal age              | 351 (11.1)  | 103 (7.16)   | 48 (6.7) | 502 (9.4) | <0.001  |
| Abortion                  | 1354 (42.7) | 422 (30.7)   | 112 (15.6) | 1908 (35.8) | <0.001  |
| Parity                    | 1142 (36.1) | 432 (30.0)   | 78 (10.9) | 1652 (31.0) | <0.001  |
| Previous CS               | 878 (27.7)  | 69 (4.8)     | 210 (29.2) | 1157 (21.7) | <0.001  |
| Gestational age           | 1289 (40.7) | 447 (31.1)   | 316 (43.9) | 2052 (38.5) | <0.001  |
| Number of foetuses        | 493 (15.6)  | 45 (3.13)    | 81 (11.3) | 619 (11.6) | <0.001  |
| Presentation              | 1124 (35.5) | 470 (32.7)   | 151 (21.0) | 1745 (32.7) | <0.001  |
| Onset of labour           | 1210 (38.2) | 391 (27.2)   | 268 (37.3) | 1869 (35.1) | <0.001  |
| Birth weight              | 400 (12.6)  | 110 (7.7)    | 67 (9.3) | 557 (10.8) | <0.001  |
| Death history in the offspring | 1372 (43.3) | 443 (30.8)   | 106 (14.7) | 1921 (36.1) | <0.001  |
| Health coverage           | 2131 (67.3) | 953 (66.3)   | 309 (43.0) | 3393 (62.7) | <0.001  |

Data are n (%) of missing data.

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Noticeably, in unstable zones the size of group 5 (iterative Caesarean section) appeared remarkably lower compared to that in stable and intermediate HZ. This trend is suggestive of an inverse care law pattern [41] whereby at-high-risk mothers living in insecure locations have less access to CS in case of need. Problematic geographical and financial accessibility, insecurity, lack of human resources—even with doctors being killed or fleeing conflict locations—may contribute to this state of affairs.

Study limitations and strengths

Using data from secondary health facilities, particularly in contexts where access to CEmOC is problematic, precludes the generalisability of this study to all the women in need of a CS in the HZ studied. The insufficiency of data did not allow us gain a deeper insight into factors driving the CS demand and accessibility. Some health centres and health posts (officially run by nurses) in DRC, mainly in rural and hard-to-reach areas, illicitly provide CS and blood transfusion services despite obvious lack in capacity to do so [33]. CS performed in these primary health care facilities are not accounted for in our analysis. We hypothesize that mothers delivering at health post or health centre level face major problems in accessing higher-level facilities offering CS and other CEmOC services in better circumstances.

Another threat to the generalisability of our results is the inclusion of only 8 health zones out of the 34 HZ that compose the South Kivu province. Some health facilities were not accessible because of insecurity and physical inaccessibility. These geopolitically enclosed areas are likely to have a different CS rate pattern and worse maternal and child health outcomes.

Of concern was also the sub-optimal records keeping in many health facilities, hindering the application of the Robson classification to a larger number of mothers. Neither could we provide insights into the other dimensions of the Robson classification, that is, the CS rate within each Robson group or the relative size of each group. The limited data availability also impeded more detailed analysis on the socio-demographic and health systems drivers of different CS patterns observed between and within conflict strata. For instance, the huge CS rate difference between Idjwi and Mwana, two rural and stable health zones, suggests that other factors than conflict play a critical role. Likewise, analysis of maternal and child outcomes of CS was unfeasible. Future studies based on prospective data at a larger scale would be needed to examine how factors such as educational attainment and socio-economic position interrelate with conflict in the expression of the CS patterns. Neither could we assess the absolute contribution of each Robson group given the fact that we did not have data to classify the profile of all women delivering within the health facilities studied.

Another limitation of this study is that our conflict variable does not take into account population displacements because of lack of data on internally displaced persons disaggregated by health zone. The cumulative death rate measure we used does not fully capture indirect effects of conflict and other forms of insecurity and violence exerted through abductions of children and women, sexual violence, illegal taxation, kidnappings, etc [24].

In spite of these limitations, our study provides a unique insight into the CS practice in conflict-affected health zones in eastern DRC. As far as we are aware, for the first time, we document the potential for applying the Robson classification system to routine service provision data from health facilities in the Kivu to help understand the drivers and singularities of CS use among the most vulnerable of the vulnerable women, those affected by lingering armed conflicts.

Conclusion

In South Kivu province, conflict exposure seems to contribute to an uneven CS rate at HZ level with at high-risks women in conflict affected settings likely to have lower access to CS.
compared to low-risk mothers in stable health zones. The road towards an optimal use of CS both in stable and insecure settings will certainly need to pass by a political will to create peace and improve access to quality CS in the regions ravaged by conflict. Strategies to improve routine service provision data collection are needed to enhance their usefulness in providing a solid basis for monitoring and appraisal of progress towards the optimal use of CS in DR Congo and other low-income countries. Additional research based on prospective data will also be necessary to generate robust and more generalisable evidence for programming and actions towards ensuring that all women, including in conflict settings, have access to quality CS.

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References
1. Betran AP, Torloni MR, Zhang J, Ye J, Mikolajczyk R, Deneux- Tharaux C, et al. What is the optimal rate of caesarean section at population level? A systematic review of ecologic studies. Reproductive health. 2015; 12(1):57.
2. Ye J, Betrán AP, Guerrero Vela M, Souza JP, Zhang J. Searching for the optimal rate of medically necessary cesarean delivery. Birth. 2014; 41(3):237–44. https://doi.org/10.1111/birt.12104 PMID: 24720614
3. World Health Organization Human Reproduction Programme. WHO Statement on caesarean section rates. Reproductive health matters. 2015;23(45):149.

4. Meara JG, Leather AJ, Hagander L, Alkire BC, Alonso N, Ameh EA, et al. Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development. The Lancet. 2015; 386 (9993):569–624.

5. Cavallo FL, Cresswell JA, França GV, Victora CG, Barros AJ, Ronsmans C. Trends in caesarean delivery by country and wealth quintile: cross-sectional surveys in southern Asia and sub-Saharan Africa. Bulletin of the World Health Organization. 2013; 91:914–22D. https://doi.org/10.2471/BLT.13.117598 PMID: 24347730

6. Betrán AP, Ye J, Moller A-B, Zhang J, Gülmezoglu AM, Torloni MR. The increasing trend in caesarean section rates: global, regional and national estimates: 1990–2014. PloS one. 2016; 11(2):e0148343. https://doi.org/10.1371/journal.pone.0148343 PMID: 26849801

7. Boerma T, Ronsmans C, Melesse DY, Barros AJ, Barros FC, Juan L, et al. Global epidemiology of use of and disparities in caesarean sections. The Lancet. 2018; 392(10155):1341–8.

8. Sobhy S, Arroyo-Manzano D, Murugesu N, Karthikeyan G, Kumar V, Kaur I, et al. Maternal and perinatal mortality and complications associated with caesarean section in low-income and middle-income countries: a systematic review and meta-analysis. The Lancet. 2019; 393(10184):1973–82.

9. Bishop D, Dyer RA, Maswime S, Rodseth RN, van Dyk D, Kluysts H-L, et al. Maternal and neonatal outcomes after caesarean delivery in the African Surgical Outcomes Study: a 7-day prospective observational cohort study. The Lancet Global Health. 2019; 7(4):e513–e22. https://doi.org/10.1016/S2214-109X(19)30036-1 PMID: 30879511

10. Poirier TJJoED. The effects of armed conflict on schooling in Sub-Saharan Africa. 2012; 32(2):341–51.

11. Guha-Sapir D, D'Aoust O. Demographic and health consequences of civil conflict. 2011.

12. Nobles J, Frankenberg E, Thomas D. The effects of mortality on fertility: population dynamics after a natural disaster. Demography. 2015; 52(1):15–38. https://doi.org/10.1007/s13524-014-0362-1 PMID: 25585644

13. Van Leeuwen M, Verkoren WJJoP, Development. Complexities and challenges for civil society building in post-conflict settings. 2012;7(1):81–94.

14. Borton J. Future of the humanitarian system: Impacts of internal changes. Medford, MA. 2009.

15. Aembe B, Dijkzeul D. Humanitarian governance and the consequences of the state-fragility discourse in the Democratic Republic of Congo’s health sector. Disasters. 2019; 43:S167–S209. https://doi.org/10.1111/disa.12336 PMID: 30821963

16. Coghill B, Brennan RJ, Ngoy P, Dofara D, Otto B, Clements M, et al. Mortality in the Democratic Republic of Congo: a nationwide survey. 2006; 367(9504):44–51. https://doi.org/10.1016/S0140-6736(06)67923-3 PMID: 16399152

17. Kandaia N-B, Mandungu TP, Mbela K, Nzita KP, Kalambayi BB, Kayembe KP, et al. Child mortality in the Democratic Republic of Congo: cross-sectional evidence of the effect of geographic location and prolonged conflict from a national household survey. BMC public health. 2014; 14(1):266.

18. Kandaia N-B, Mandungu TP, Emina JB, Nzita KP, Cappuccio FPJb. Malnutrition among children under the age of five in the Democratic Republic of Congo (DRC): does geographic location matter? 2011; 11(1):261.

19. Dialogue I-C. Political Negotiations on the Peace Process and on Transition in the DRC: Global and Inclusive Agreement on Transition in the Democratic Republic of the Congo. Pretoria; 2002.

20. Human Rights Watch. World Report. United States of America: Human Rights Watch, 2019.

21. Ministère du Plan et Suivi de la Mise en œuvre de la Révolution de la Modernité (MPSMRM) MrdlSPMrM, Enquête Démographique et de Santé en République Démocratique du Congo 2013–2014. Rockville, Maryland, USA: MPSMRM, MSP et ICF International, 2014.

22. Boerma T, Tappis H, Saad-Haddad G, Das J, Melesse DY, DeJong J, et al. Armed conflicts and national trends in reproductive, maternal, newborn and child health in sub-Saharan Africa: what can national health surveys tell us? BMJ Global Health. 2019; 4(Suppl 4):e001300. https://doi.org/10.1136/bmjgh-2018-001300 PMID: 31297253

23. World Health Organization Human. Robson Classification: Implementation Manual. Geneva: World Health Organization. Geneva: 2017 2017. Report No.

24. Congo Research Group. Congo, Forgotten: The Numbers Behind Africa’s Longest Humanitarian Crisis. Center On International Cooperation, New York University, Group CR; 2019 August 2019. Report No.

25. UNOCHA. RD Congo—Sud-Kivu: Qui fait Quoi Où? - 3W Opératinel au 30 septembre 2019. United Nations Office for the Coordination of Humanitarian Affairs, 2019.
26. Robson MS. Classification of caesarean sections. Fetal and maternal medicine review. 2001; 12(1):23–39.

27. Vogel JP, Betrán AP, Vindevoghel N, Souza JP, Torloni MR, Zhang J, et al. Use of the Robson classification to assess caesarean section trends in 21 countries: a secondary analysis of two WHO multicountry surveys. The Lancet Global Health. 2015; 3(5):e260–e70. https://doi.org/10.1016/S2214-109X(15)70094-X PMID: 25866355

28. Nakamura-Pereira M, do Carmo Leal M, Esteves-Pereira AP, Domingues RMSM, Torres JA, Dias MAB, et al. Use of Robson classification to assess cesarean section rate in Brazil: the role of source of payment for childbirth. Reproductive health. 2016; 13(3):128.

29. Litorp H, Kidanto HL, Nyström L, Darj E, Essén B. Increasing caesarean section rates among low-risk groups: a panel study classifying deliveries according to Robson at a university hospital in Tanzania. BMC pregnancy and childbirth. 2013; 13(1):107.

30. Tanaka K, Mahomed K. The ten-group Robson classification: a single centre approach identifying strategies to optimise caesarean section rates. Obstetrics and gynaecology international. 2017;2017.

31. Kacerauskienė J, Bartusevičienė E, Railaitė DR, Minkauskiene M, Bartusevičius A, Klucinskas M, et al. Implementation of the Robson classification in clinical practice: Lithuania’s experience. BMC pregnancy and childbirth. 2017; 17(1):432. https://doi.org/10.1186/s12884-017-1625-9 PMID: 29262810

32. INS. Enquête par groupes à indicateurs multiples, 2017–2018, rapport de résultats de l’enquête. Kinshasa, République Démocratique du Congo. Kinshasa: 2019.

33. Mpunga Mukendi D, Chenge F, Mapatano MA, Criel B, Wembodanga G. Distribution and quality of emergency obstetric care service delivery in the Democratic Republic of the Congo: it is time to improve regulatory mechanisms. Reproductive health. 2019; 16(1):102. https://doi.org/10.1186/s12978-019-0772-z PMID: 31307497

34. UNOCHA. RD Congo—Sud-Kivu: Qui Fait Quoi Ou ` | 3W Opérationnel au 30 septembre 2019. United Nations Office for the Coordination of Humanitarian Affairs, 2019.

35. Ahuka OL, Chabikuli N, Ogunbanjo GA. The effects of armed conflict on pregnancy outcomes in the Congo. International Journal of Gynecology and Obstetrics. 2004; 84(1):91–2. https://doi.org/10.1016/s0020-7292 (03)00328-x PMID: 14698840

36. Keasley J, Blickwedel J, Quenby S. Adverse effects of exposure to armed conflict on pregnancy: a systematic review. BMJ global health. 2017; 2(4):e000377. https://doi.org/10.1136/bmjgh-2017-000377 PMID: 29333283

37. Lee AC, Blencowe H, Lawn JEJTLGH. Small babies, big numbers: global estimates of preterm birth. 2019; 7(1):e2–e3.

38. Macaulay S, Buchmann EJ, Dunger DB, Norris S, Research G. Reliability and validity of last menstrual period for gestational age estimation in a low-to-middle-income setting, 2019; 45(1):217–25.

39. Smits J, Monden C. Twinning across the developing world. PLoS One. 2011; 6(9):e25239. https://doi.org/10.1371/journal.pone.0025239 PMID: 21980404

40. Vogel JP, Torloni MR, Seuc A, Betrán AP, Widmer M, Souza JP, et al. Maternal and perinatal outcomes of twin pregnancy in 23 low- and middle-income countries. PLoS one. 2013; 8(8):e70549. https://doi.org/10.1371/journal.pone.0070549 PMID: 23936446

41. Hart JT. The inverse care law. The Lancet. 1971; 297(7696):405–12.