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Prioritising human resource investments in a context of scarce resources: exploring options for the Burundian EmONC network

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Abstract:	Introduction Provision of quality emergency obstetric and neonatal care (EmONC) could enable low- and middle-income countries (LMICs) to deliver on the maternal and newborn health (MNH) agenda 2030. However, low income countries are struggling to deliver quality care because of scarce and poorly directed resources, especially human resources. Burundi's network of 112 EmONC facilities has severe workforce deficits but addressing all of these may not be possible. We developed and employed a prioritization framework that might help inform policy makers to better direct limited resources, an approach of potential relevance to other LMICs. Methods We conducted a cross-sectional survey of all Burundian EmONC facilities (n=112) documenting available human resources and collated annual data on deliveries, maternal complications, and health outcomes covering 2021. We developed a categorisation approach based on these data and explored the additional value of

	maternal mortality as a categorising variable with funnel plots, including use of readjustments for overdispersion and Winsorization. Results Facility workloads are not aligned with their EmONC classification. Some Burundian BEmONC facilities perform caesarean sections and blood transfusions and handle more deliveries and maternal complications than CEmONC facilities. We identified 11 BEmONC and 13 CEmONC facilities that provide 30% of all deliveries and manage 35% of maternal complications but have 15% of available EmONC human resources that could be prioritised for workforce investment. Available data on maternal mortality was very variable and not useful for prioritisation. Conclusion Efforts to invest across the EmONC network in line with existing human resource and other resource normative policies may not be affordable and simply basing investment on assigned B/CEmONC status may poorly allocate scarce resources. If resources are limited, investments in 24 priority EmONC facilities may be more efficient but such decisions should be informed ideally by better data on delivery outcomes and economic evaluations.
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April 11th, 2025

Re: Cover Letter

Dear Editors,
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I am submitting our health workforce policy manuscript for consideration into the collection *"The Health and Care Workforce: how to respond to multiple crises and new health priorities?"* advertised online (link). I am Burundian national and resident, junior researcher in the Faculty of Medicine of the University of Burundi currently completing a full-time PhD at Oxford University. As part of the PhD research, previous works have been published in BMJ series, I developed and employed a prioritization framework that might help inform Burundian health policy makers to better direct limited resources to strengthen the special maternity hubs, an approach of potential relevance to other LMICs.

I hope you will find our work interesting and relevant to the above collection – as we think it is.

I submit this work on behalf of all co-authors who have proofread the final version and approved submission.

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Title Page (showing Author Details)

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Prioritising human resource investments in a context of scarce resources: exploring options for the Burundian EmONC network

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Declarations

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Declaration of Interest statement
The authors declare no conflicts of interest.

Availability of data and files
This study used datasets from the main EmONC facility survey and routine monitoring data which are not publicly available as primarily owned by the Burundian Ministry of Health (MoH) and are bound by a strong data sharing policy which does not permit authors to share them. However, these data can be obtained by sending a reasonable request to the reproductive, maternal, newborn, child, and adolescent's health programme of the Burundian MoH. The corresponding author can share STATA command files upon request.

Authors' contributions
DH conceptualized and wrote the study protocol, engaged policy makers and stakeholders in Burundi, sought ethics approvals and the World Health Organization's (WHO) funding for fieldwork, curated and analysed data, and wrote the first and final drafts of the manuscript. AL, CN, and ME contributed substantially to the study conceptualization, guided data analysis, and reviewed the drafts manuscript. JBN, AN, AB, JN, ESDN, and SB reviewed the study protocol and helped to coordinate stakeholder discussions. PN† contributed to the study conceptualisation but died during the course of the study conduct. All authors read and approved the final manuscript.

Ethics approval and consent to participate

This study was approved by the Human Research Ethics Committee of the Faculty of Medicine of the University of Burundi (Ethics certificate FM/CE/01/M/2022) and the University of Oxford's Tropical Research Ethics Committee (OxTREC approval reference: 516-22). Participation was voluntary and all participants signed a written informed consent form.

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Consent for publication

Not applicable.

Prioritising human resource investments in a context of scarce resources: exploring options for the Burundian EmONC network

Abstract

Introduction

Provision of quality emergency obstetric and neonatal care (EmONC) could enable low- and middle-income countries (LMICs) to deliver on the maternal and newborn health (MNH) agenda 2030. However, low income countries are struggling to deliver quality care because of scarce and poorly directed resources, especially human resources. Burundi's network of 112 EmONC facilities has severe workforce deficits but addressing all of these may not be possible. We developed and employed a prioritization framework that might help inform policy makers to better direct limited resources, an approach of potential relevance to other LMICs.

Methods

We conducted a cross-sectional survey of all Burundian EmONC facilities (n=112) documenting available human resources and collated annual data on deliveries, maternal complications, and health outcomes covering 2021. We developed a categorisation approach based on these data and explored the additional value of maternal mortality as a categorising variable with funnel plots, including use of readjustments for overdispersion and Winsorization.

Results

Facility workloads are not aligned with their EmONC classification. Some Burundian BEmONC facilities perform caesarean sections and blood transfusions and handle more deliveries and maternal complications than CEmONC facilities. We identified 11 BEmONC and 13 CEmONC facilities that provide 30% of all deliveries and manage 35% of maternal complications but have 15% of available EmONC human resources that could be prioritised for workforce investment. Available data on maternal mortality was very variable and not useful for prioritisation.

Conclusion

Efforts to invest across the EmONC network in line with existing human resource and other resource normative policies may not be affordable and simply basing investment on assigned B/CEmONC status may poorly allocate scarce resources. If resources are limited, investments in 24 priority EmONC facilities may be more efficient but such decisions should be informed ideally by better data on delivery outcomes and economic evaluations.

Keywords: EmONC, scarce resources, facility prioritization, allocative efficiency, Burundi.

Introduction

To accelerate progress towards achieving the 60% and 50% reductions in maternal and newborn mortality rates that Burundi pledged to attain from 2015 until 2030,[3,4] this country formed in 2017 a "maternity network" of 112 facilities designated as emergency obstetric and neonatal care (EmONC) facilities.[5] These facilities comprise 59 primary health facilities and 53 hospitals assigned as basic and comprehensive EmONC facilities (BEmONC and CEmONC) respectively and consist of 82 (73%) public and 20 (27%) religious and private facilities. They are supported by a specific policy that defines how they should be strengthened with appropriate resources to maximise their readiness to provide quality care for emergency obstetric and newborn complications.[4-6] Moreover, they are strategically distributed nationally to improve accessibility;[7,8] allowing more than 97% of the population in most districts to reach an EmONC facility within two hours (Supplemental material S1). Even though these special maternities represent less than 8% of all health facilities, records indicate that they perform a

third of the 85% of deliveries annually currently taking place in health facilities[9] and manage approximately two-thirds of obstetric complications.[5,10]

Although the Burundian EmONC network represents a clear and rational policy objective in prior work we identified substantial resource deficits even when compared with modest national resource recommendations.[11,12] Total deficits across the 112 EmONC facilities amounted to 162 medical doctors, 1005 midwives and nurses, 132 delivery rooms, and 678 and 156 maternity and newborn care beds respectively amongst others, with deficits unevenly distributed across facilities.[12] To address these deficits, a budget amounting to approximately United States dollar (US$) 32.9 million would be required over the next five years, representing an increase in the Burundian total health budget of about 6% annually.[12]

Burundi may not successfully mobilise such a large budget increase to cover these basic needs in the near term. This paper explores whether some facilities might be targeted for investment with a view to optimising use of scarce resources with a continued focus on equity. We examine in this paper an approach to prioritise facilities based on prevailing workloads, existing resources, and maternal mortality. First, we examined whether a facility's official B/CEmONC designation is meaningful by exploring the relationship between facility type, workload and numbers of women with delivery complications, hypothesising that BEmONC facilities with fewer resources should deliver fewer women with complicated deliveries. Absence of these expected relationships prompted us to develop a prioritization framework to identify facilities with high delivery workloads and greater numbers of complications but with fewer resources. Such facilities we reason, if they can be identified, may be priorities for investment. As part of this work we explored the relationship between maternal mortality, workloads and human resources. However, we show that mortality is likely to be an unreliable criterion to prioritise facilities.

Methods

Study design and data description

We collected EmONC facility (n=112) records of deliveries, maternal complications, and deaths for the year 2021. Maternal complications comprised prolonged or labour dystocia, post abortion complications, maternal infections, postpartum haemorrhage, severe preeclampsia or eclampsia, and uterine rupture. We focused on maternal conditions as accurate determination of newborn outcomes was not possible from routine records. In June and July 2022 we assessed the infrastructure available and the presence of delivery care professionals namely doctors, midwives, and nurses specifically assigned to provide maternity services using a survey approach described in detail elsewhere.[13]

Examining the EmONC facility standard classification

The Burundian EmONC policy indicates that BEmONC facilities should have 1 delivery room with 2 delivery tables and 8 maternity beds, 1 midwife and 2 nurses. CEmONC facilities are supposed to have 2 delivery rooms with 4 and 22 delivery tables and maternity beds respectively, a doctor and 4 midwives and 9 nurses.[4,12] This basic and comprehensive facility status is intrinsic to the Burundian EmONC network design where larger facilities providing a full set of assisted delivery services including caesarean sections support peripheral smaller facilities and receive referrals from them. To examine whether this standard EmONC classification into B/CEmONC facilities holds, we explored statistically and graphically the relationships between facility type and deliveries and complications expecting that CEmONC facilities should perform more deliveries and manage considerably more complications than BEmONC facilities. Additionally, we examined which facilities performed CEmONC 'signal functions' focusing on caesarean sections and blood transfusion.[14]

Conceptualising priority EmONC facilities

Next, we developed a logical framework for grouping EmONC facilities based on actual deliveries, complications, available human resources, and maternal mortality as conceptualised in Figure 1 to

isolate those worthy of priority investment assuming that Burundi cannot raise in the short run the estimated US$ 32.9 million to cover the network-level EmONC needs.[12] To do this, we created for each input variable high, moderate, and low levels and combined these to identify high priority and priority facilities (Figure 1). Conceptually, 'high priority' EmONC facilities are those managing high delivery volumes together with high levels of complications having few or moderate human resources. 'Priority' facilities have moderate workloads and complications with few human resources. Although mortality was an unreliable criterion to classify facilities it was included to demonstrate conceptually (high) priority facilities where an investment would strategically accrue more health benefits if quality and reliable mortality data is available.

***** Figure 1 should be placed here ******

Data analysis

To categorise facilities as schematised in Figure 1, we first explored statistically and graphically the distributions of deliveries and complications across all EmONC facilities; testing for normality. These basic explorations revealed considerable variability better addressed with a statistical method to handle data overdispersion. We used the overdispersion z-score method which is recommended for distributions when the influence of chance is variable or low and when sample sizes are highly variable across organisations.[1,15] This method uses the standard deviation (σ_o) of observed data and identifies organisations lying at the edge of the distribution using $\pm\ 1.96\ \sigma_o$. We classified EmONC facilities in the negative and positive tails into low and high facility categories for our indicators of interest respectively and those within the 95% confidence interval into the moderate category. We used the reliability (λ) test to confirm this classification (see Equation 1 of Box 1).[15] Using this approach to developing categories we created a matrix of facilities based on their high, moderate or low categorisation for the three parameters; delivery workload, numbers of delivery complications, and human resources.

Box 1. In our context, reliability λ refers to the Spearman Brown or inter-unit reliability which is a measure of how reliably different units can be distinguished, ranked, or classified based on the overdispersion method and ranges from 0 to 1. When reliability is low, it is difficult to distinguish amongst organisations. Statistically, Spearman Brown reliability is formally defined as the ratio between the true underlying variance, σ_o^2, and the within organisation variance, σ_w^2, and the sample size n as given by Equation 1:

$$\lambda = \frac{\sigma_o^2}{\sigma_o^2 + \frac{\sigma_w^2}{\sqrt{n}}}$$ **Equation 1**

Without assessing reliability, it is difficult to ascertain an organisation to a particular category and to appraise the degree of resultant misclassification. Even though there is no commonly agreed reliability benchmark, the literature argues that more than half of flagged organisations using the overdispersion z-score method are misclassified if reliability is below 0.7. In other words, reliability needs to reach at least 0.7 for 50% of units to be correctly classified and 0.9 to nearly eliminate misclassification.

$$\Phi = \frac{1}{I}\sum_{i=1}^{i=n}\frac{(y_i - \theta_o)^2}{g(\theta_o)}\zeta_i$$ **Equation 2**

Adjusting funnel plots control limits such that ρ = $\Phi\sigma$ where ρ corresponds to the new control limit and Φ is the overdispersion parameter. Where $g(\theta_o)$ equals σ^2 for known θ_o and for continuous y_i outcomes. We have a sample I units that we assume all to be in-control and set ζ_i as the effective sample size. Consequently, $I = \zeta_i$. Empirical demonstrations of these assumptions have been comprehensively developed elsewhere.[1,2]

We explored the use of maternal mortality as an additional parameter to categorise facilities using funnel plots[2,16] useful to study variability of performance indicators between institutions or areas and for identifying outliers.[17-19] However, one major shortcoming of funnel plots is accounting for overdispersion.[20,21] To address the above important setback, we readjusted control limits to account

for this using empirically proven approaches[1,2] (see Equation 2 of Box 1). We also performed a range of sensitivity analyses informing our use of methods to account for overdispersion in creating categories and employing funnel plots (see Supplementary material S2).

Finally, we used 2D charts to highlight 3 EmONC facility categories pertinent for policy attention. The first category comprises facilities with both high deliveries and complications and the second and third facility categories combine high deliveries and moderate complications and moderate deliveries and high complications respectively. We added a third criterion; human resources; to identify amongst these three categories facilities having low or moderate human resources flagging them as priority facilities (Figure 1). For national policy makers we show using the 2D chart where all 112 facilities lie in the overall, nine level categorisation approach highlighting those with relatively more human resources for their level of workload.

Results

Facility functions are not aligned with their standard EmONC classification

Contrary to expectations, the ratio of maternal complications to deliveries appears to be similar in BEmONC and CEmONC facilities (Figure 2). This was not accounted for by BEmONC having much smaller workloads and infrequent delivery complications. In fact some BEmONC facilities are busier than larger hospitals with for instance 11 BEmONC facilities reportedly performing five and more deliveries daily on average while another 10 and 21 CEmONC facilities reportedly performed fewer than 3 and 4 deliveries daily respectively. The only more consistent difference concerns human resources with CEmONC facilities sometimes enjoying more delivery professionals although even within CEmONC facilities staffing did not necessarily correspond with workload. For instance, for BEmONC facilities having in the vicinity of 1500 deliveries and 500 complications per annum Figure 2a staffing levels and skill-mix could be quite different, a pattern also observed for CEmONC facilities (Figure 2b). CEmONC facilities managing fewer than 2000 deliveries and 500 complications annually might have between one to eight nurses and midwives assigned to provide these services and may be with or without a doctor. In fact, data suggest several hospitals have more than 10 nurses and midwives available to provide delivery care but no assigned doctor while contrary to global and Burundian EmONC standards, we identified 3 BEmONC facilities that have a medical doctor who performs caesarean sections and blood transfusions.

***** Figure 2 should be placed here ****

Variation in maternal mortality across EmONC facilities

Maternal mortality varied very widely across facilities and was thus unreliable for prioritising them. We demonstrated this by exploring its variation relative to workloads and human resources using funnel plots with various data transformations used to improve results accuracy. This included adjustment of control limits using the overdispersion parameter, data winsorization, and controlling for outlying facilities (Supplemental material S3). In Figure 3 we show that EmONC facilities record an average of about 380 maternal deaths per 100,000 deliveries (maternal mortality ratio; MMR). The unadjusted funnel plot would suggest that most facilities lie outside standard control limits, implying that almost all Burundian EmONC facilities have special cause variation influencing MMR. Employing winsorization reduces the number of facilities with apparent special cause variation influencing MMR with 26/112 (23.2%) appearing to have much higher than expected MMR Figure 3b. However, it can be seen that many facilities reported zero maternal deaths, even amongst the category with high workloads, high numbers of complications and lower human resources and further efforts to adjust for variation did not provide a strong rationale for using MMR to prioritise facilities (Supplemental material S3).

***** Figure 3 should be placed here ****

Identifying priority EmONC facilities

Results of the univariate facility categorisation in Supplemental material S4 show that facilities are correctly classified (i.e., reliability scores $\lambda > 0.7$) across low, moderate, and high categories with a relatively balanced distribution although the low category appears to be more prevalent. Next, we diagnosed using the bivariate criterion in Matrix 1 three sets of facilities useful for policy attention; 28 facilities that perform large volumes of deliveries with high rates of maternal complications, 13 facilities handling high volumes of deliveries and with moderate numbers of complications, and 14 facilities manging moderate delivery volumes but with high numbers of complications.

Of those 28 facilities handling high deliveries and complications, 9 and 11 have low and moderate human resources, respectively. These 20 facilities comprising 8 BEmONC and 12 CEmONC thus appear to be high priority facilities (Figure 1) and constitute a sensible target for priority workforce investment. We further identified from the 13 and 14 high/moderate deliveries and moderate/high complications categories a group of 4 facilities comprising 3 BEmONC and 1 CEmONC that have low human resources which we reason should also be priority facilities.

The total 24 priority facilities were identified distributed across 15 of the 18 provinces of Burundi, with very significant disparities between their workloads and available human resources. These facilities perform nearly 30% of all deliveries taking place within the EmONC network and manage approximately 35% of obstetric complications. However, they are allocated only 15% (57 out of 374) of the total workforce in the EmONC system. Notably, 5 out of 12 priority CEmONC facilities lack a medical doctor and 13 out of 24 priority facilities do not have a midwife.

***** Matric 1 should be placed here ****

Discussion

We proved in this study that the standard B/CEmONC classification in Burundi's context does not fulfil expectations and developed a framework that enables a recategorization of EmONC facilities highlighting those deserving to be prioritised for workforce investment. Allocating resources where they are most needed is strategically beneficial for Burundi because this low-income country cannot immediately address identified needs by investing US$33 million over 5 years to strengthen all the 112 designated EmONC facilities in line with its current policy norms.[12] In fact, even if the necessary budget was available allocating investments based on Burundi's normative policy might well exacerbate equity gaps by strengthening facilities with lower workloads as much as those with very high service demand.

We demonstrated that the Burundian B/CEmONC facility classification does not respond to expected standards. First, while international guidelines recommend linking 4 BEmONC to 1 CEmONC facilities per 500,000 population,[22] the Burundian EmONC network comprises 59 and 53 B/CEmONC facilities respectively; amounting to 1.1 BEmONC facilities for each CEmONC facility per approximately 107,000 population. Second, workload analysis revealed that 11 BEmONC facilities are between 1.5 to 2 times busier than a set of 31 CEmONC facilities despite the CEmONC facilities sometimes having considerable capacity advantages.[12] In fact, we show in Figure 2 and statistically that both facility types manage comparable proportions of maternal complications per deliveries indirectly indicating serious issues with the referral system. Additionally, although BEmONC facilities are by design not permitted to perform caesarean sections or blood transfusion,[22,23] we found a medical doctor who offers these services in 3 BEmONC facilities; conversely 22 CEmONC facilities that lack a doctor cannot perform caesarean section.[12]

Based on the misalignment in facility categorisation, one option is reviewing and limiting the number of designated EmONC facilities to strategically deploy and focus scarce resources where they are most needed. Beyond Burundi studies show that EmONC maternities in LMICs struggle to offer quality care partly because countries form ambitiously large networks of facilities that are difficult to

make and keep fully operational.[24-27] We show that annual maternal mortality data is unsuitable for prioritising facilities as reported mortality rates are highly over-dispersed. One possible explanation for this is that EmONC facility staff may underreport maternal deaths linked to financial incentives as part of the performance based financing scheme.[28,29] This possibility is supported by identifying 31 EmONC facilities that reported zero maternal deaths over a period of 12 months including busier facilities delivering up to 3351 women and that collectively report dealing with more than 55% of delivery complications. Our proposed prioritization framework therefore focuses on 24 facilities comprising 11 BEmONC and 13 CEmONC facilities that are severely understaffed but manage high volumes of deliveries and complications. These facilities perform about one third of deliveries and manage 35% of complications although they have less 15% of the total EmONC network workforce.

Our study has two major limitations. First, our approach to facility categorization may result in resource allocation to facilities where mortality is not the highest. This would reduce allocative efficiency and the overall impact. Secondly we were unable to include neonatal outcomes in our analyses as accurate records were generally lacking for stillbirths and neonatal mortality. Thus, we rely on maternal records as a proxy indicator of both maternal and neonatal health under the hypothesis that strengthening facilities to improve quality maternal care would translate into better neonatal health outcomes.[30,31] A further limitation is that our focus on resource allocation was limited to health workers despite there being wider prevailing capacity deficits.[12]

Conclusion

This study of the Burundian EmONC network demonstrates that the current policy on B/CEmONC facility categorization is misleading in practice with Burundian BEmONC facilities often managing higher volumes of normal and complicated deliveries than CEmONC facilities although the latter are relatively better resourced. We proposed an empirical framework that helps to categorise facilities using prevailing workloads and human resources demonstrating how it could identify facilities that are a priority for investment in the context of highly constrained resources. Accurate and long-term mortality data if available could further inform prioritisation of investments as could more accurate information on needed non-human resources. These analyses could be further developed through subsequent economic and budget impact evaluations to better inform policymakers of both the likely costs and expected benefits from strengthening priority or all EmONC facilities. These analyses would also benefit from considering the effects on equity of targeted investments.

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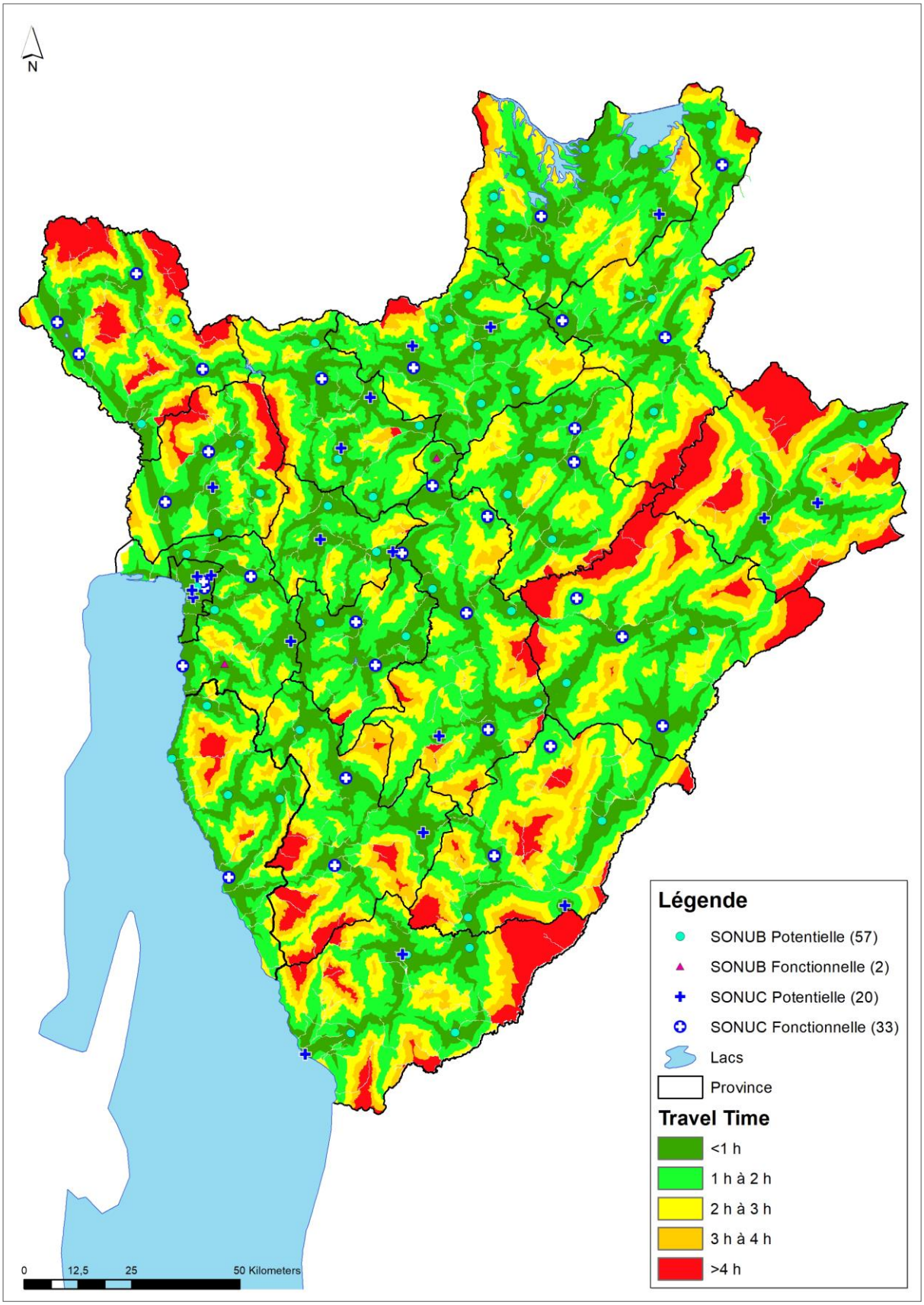
Supplemental material S1. Geographical distribution of EmONC facilities

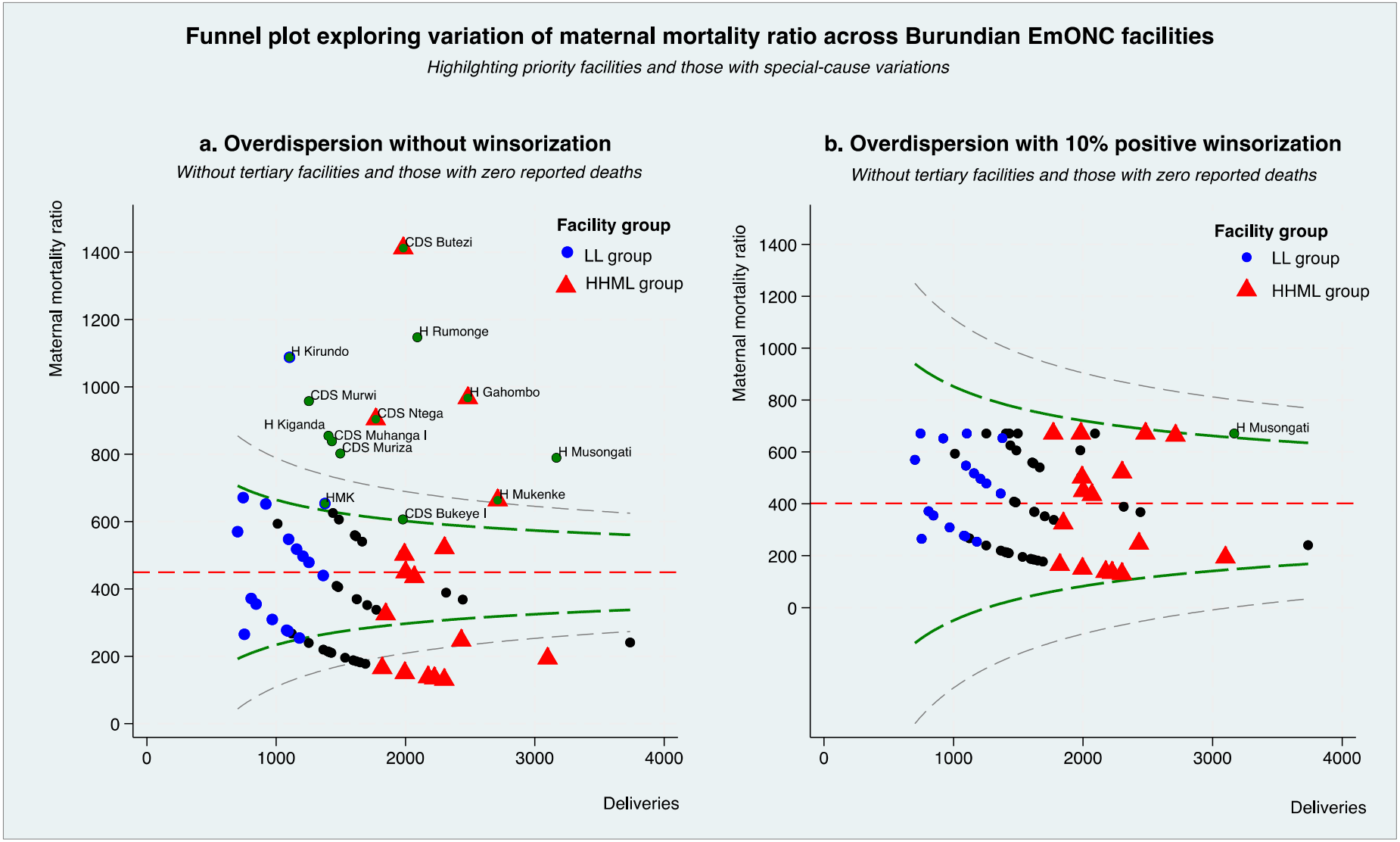


Supplemental material S1 is the map of Burundian EmONC network in 2020. The map shows that three years after the creation of the network only 2 BEmONC and 33 CEmONC facilities where functional implying that 57 BEmONC facilities did not offer the whole set of seven signal functions and 20 CEmONC facilities failed to offer the full set of nine signal functions. 'Lacs' means for Lake Tanganyika.

Supplemental material S2.

Sensitivity analysis

Even though the overdispersion z-score method minimised data issues, we remained doubtful of the methods robustness so we performed sensitivity analysis in two folds with an aim to address uncertainties. Firstly, we performed structural sensitivity analysis by purposively excluding big hospitals with outlying numbers of human resources and EmONC facilities with zero maternal deaths assuming that this is contextually inaccurate. Indeed, an EmONC facility in Burundi recording zero maternal death over a period of 12 months is less likely; deaths are rather presumably underreported to accrue performance-based financial rewards. Secondly, we played on parameters by implementing one-sided MMR winsorization which is a data transformation procedure that records outliers of the distribution to less extreme values.[32] We did not perform two-sided winsorization because mortality cannot be negative and was found to be positively skewed with zero inflation. EmONC facilities that consistently remained outside the overdispersed control limits even after data winsorization and outlying facility removal were considered to be very concerning indeed.



Supplemental material S3 is the funnel plot comparing MMR variations across Burundian EmONC facilities without winsorization (Figure a) and with winsorization (Figure b). The horizontal dotted red line corresponds to the expected MMR, the bold dotted green lines correspond to the 95% (i.e., p-value 0.05 and 2 standard deviations) control limits, while the dotted grey lines encapsulate 99.8% (i.e., p-value 0.002 and 3 standard deviations) lower and upper limits. Generally, facilities inside these limits are "under control" while those outside them are not in control and warrant further investigation. Typically, as the outcome in MMR, fair interpretation would be that facilities below the lower limit (i.e., those with lower MMR than expected under normal circumstances) are "excellent" performers (beyond expectation) and those above the upper limit are worrisome as they record higher MMR than expected under normal conditions. LL stands for low deliveries and low complications; HHML means high deliveries, high complications, and moderate or low delivery care professionals.

Supplementary material S4.

	Low category n (%) facilities	**Moderate category** n (%) facilities	**High category** n (%) facilities	**Reliability score (λ)**
Deliveries	[331 – 1407] 48 (42.86)	[1409 – 1643] 23 (20.54)	[1644 – 3737] 41 (36.61)	> 0.91
Maternal complications	[22 – 383] 54 (48.21)	[384 – 496] 16 (14.29)	[497 – 1538] 42 (37.50)	> 0.91
Human resources	[0 – 2] 56 (50.00)	[3 – 4] 32 (28.57)	[5 – 18] 24 (21.43)	> 0.77

Supplemental material S4 summarises EmONC classification using the overdispersion z-score method. We define for each metric the benchmarking criteria in square brackets and in paratheses the number and proportion of facilities falling into each category. Reliability scores $\lambda > 0.7$ indicate that facilities are correctly classified while chances of facility misclassification are almost eliminated as λ approaches 1.

Supplementary material S5. List of study stakeholders

Names	Position and institution
1. Dr Jean Baptiste Nzorironkankuze	Permanent Secretary, Ministry of Health (MoH)
2. Dr Oscar Ntihabose	Director General Health Services, MoH
3. Dr Ananie Ndacayisaba	Director of the RMNCAH Programme, MoH
4. Dr Zacharie Kubwimana	Director of Programme, MoH
5. Dr Theophile Bigayi	Deputy Director RMNCAH Programme, MoH
6. Prof Sylvestre Bazikamwe*	Professor of Gynecology and Obstetrics , University of Burundi
7. Dr Jeanine Ndayisenga**	Paediatrician Research Fellow, National Institute of Public Health
8. Dr Yolande Magonyagi	National Programme Officer SRH, United Nations Population Fund (UNFPA)
9. Dr Eugenie Siga Diane Niane	Programme Officer RMNCAH, World Health Organization (WHO)
10. Dr Brigitte Ndelema	National Programme Officer RMNCAH, WHO
11. Dr Aristide Bishinga	EmONC Specialist, Japan International Cooperation Agency (JICA)
12. Dr Dorothee Ntakirutimana	Health Specialist, United Nations Children's Fund (UNICEF)
13. Dr Josiane Nijimbere	Scientist RMNCAH Programme, MoH
14. Dr Jean Claude Mugisha	Scientist RMNCAH Programme, MoH
15. Dr Innocent Nkurunziza	Secretary, MoH
16. Dr Anaclet Nahayo	Director of HIS, MoH
17. Olivier Gahungere, Mr	Statistician, RMNCAH Programme, MoH
18. Thierry Nzeyimana, Mr	Monitoring and Evaluation, RMNCAH Programme, MoH
19. Daniel Habonimana, Mr	Monitoring and Evaluation, RMNCAH Programme, MoH
20. Souverienne Bucumi, Mrs	Monitoring and Evaluation, RMNCAH Programme, MoH
21. Rose Simone Ndayiziga, Mrs	Scientist, National HIV/AIDS programme, MoH
22. Nadine Muhimbare, Ms.	Cabinet Secretary, MoH
23. Therence Nduwarugira, Mr	Scientist, UNFPA

*He also represents the Burundian Association of Gynaecology-Obstetricians (AGOB)
**She also represents the Burundian Association of Neonatology (ABUNE)

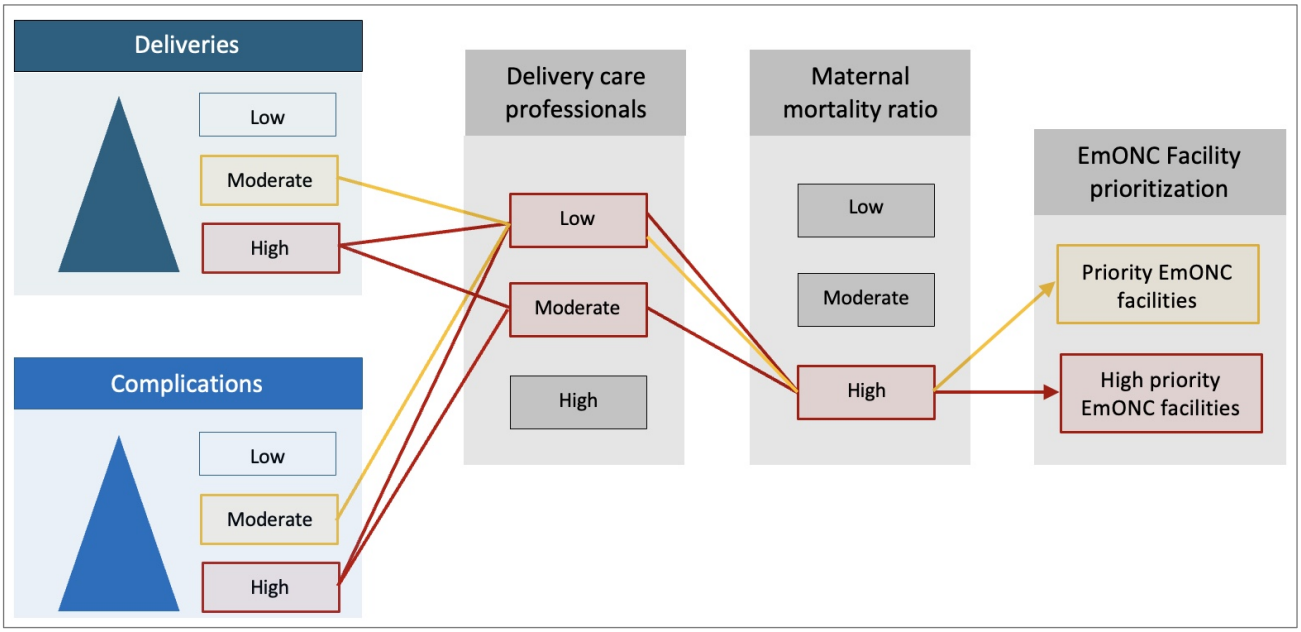


Figure 1. Conceptualisation of EmONC priority facilities. 'High priority' facilities i.e., those worthy of a priority investment to avert maternal deaths are those facing high deliveries and correspondingly high maternal complications with low or moderate levels of human resources and where maternal mortality is highest. EmONC facilities with moderate workloads, fewer human resources, and more deaths are considered as 'priority' investment facilities.

Figure

Click here to access/download;Figure;Figure 2. Deliveries and complications.docx

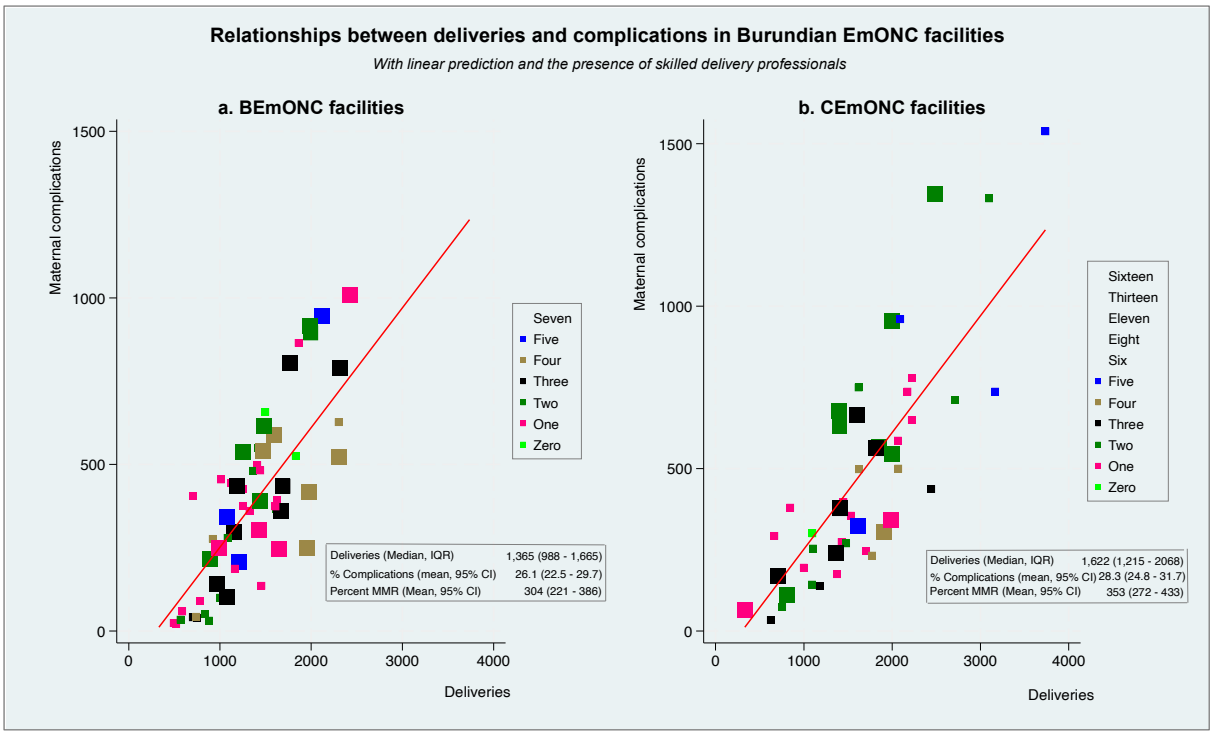


Figure 2 examines the relationships between deliveries and maternal complications with human resources by facility type. The symbol colour represents the number of midwives and nurses combined and the size corresponds to the presence or absence of a midwife in BEmONC facilities and that of a doctor in CEmONC facilities. Therefore, big makers in *Figure 2a* mean the presence of a midwife and that of a doctor in *Figure 2b*.

Figure

Click here to access/download;Figure;Figure 3. Funnel plot.docx

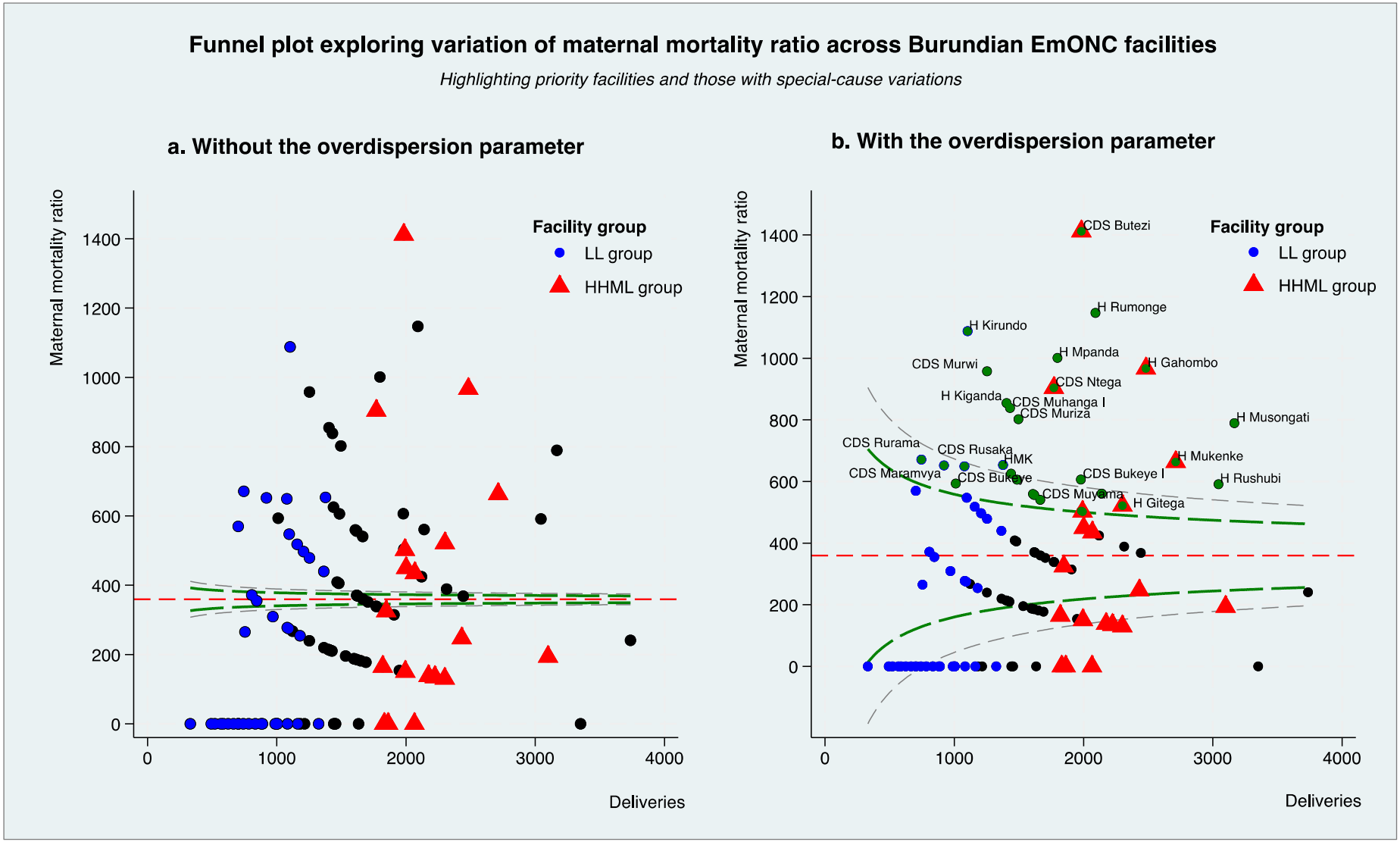
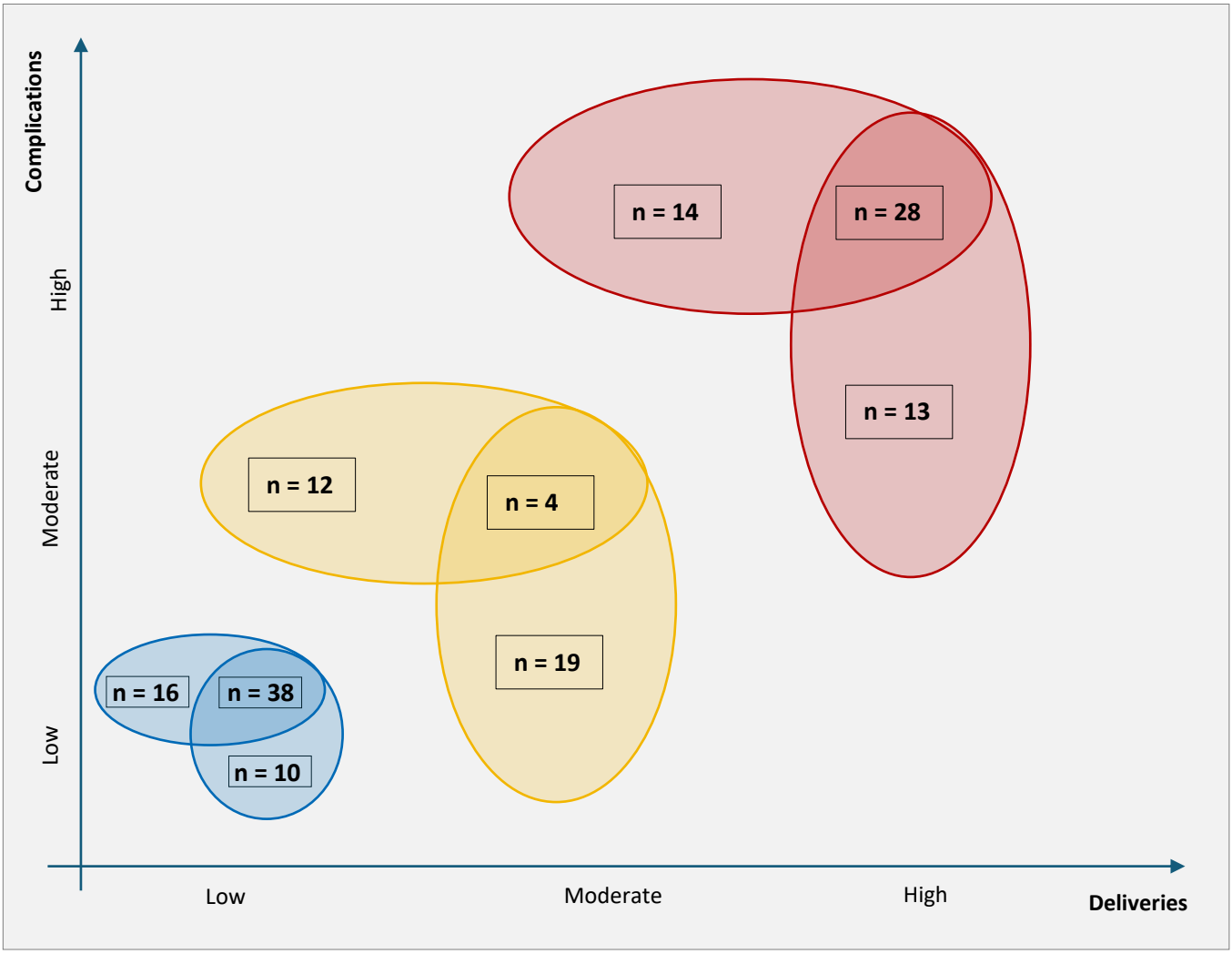


Figure 3 is the funnel plot comparing MMR variations across Burundian EmONC facilities with unadjusted control limits (Figure 3a) and adjusted control limits (Figure 3b). The horizontal dotted red line corresponds to the expected MMR, the bold dotted green lines correspond to the 95% (i.e., p-value 0.05 and 2 standard deviations) control limits, while the dotted grey lines encapsulate 99.8% (i.e., p-value 0.002 and 3 standard deviations) lower and upper limits. Generally, facilities inside these limits are "under control" while those outside them are not in control and warrant further investigation. Typically, as the outcome in MMR, fair interpretation would be that facilities below the lower limit (i.e., those with lower than expected MMR under normal circumstances) are "excellent" performers as recording fewer deaths and those above the upper limit are worrisome as they record higher MMR than expected under normal conditions. LL stands for low deliveries and low complications; HHML means high deliveries, high complications, and moderate or low delivery care professionals.

Figure

Click here to access/download;Figure;Matrix 1. Facility categorization.docx



Matrix 1 summarises the number of facilities using a combination of different levels of workloads. For instance, Supplemental material S4 indicates that 41 and 42 facilities belong to the high deliveries and high complications groups respectively using the overdispersion z-score method and Matrix 1 further shows that 28 of these two groups of facilities performed high levels of both deliveries and complications. Similar analyses were done using moderate and low levels of deliveries and complications.

Highlights

What is already known about the topic?

- Effective emergency obstetric and neonatal care (EmONC) can avert three-fourths of maternal mortality but many African countries including Burundi are not realising these gains because of persistently weak health systems.
- Often EmONC facility prioritization and linked resource allocation are based on normative policies that pay insufficient attention to service delivery patterns and outcomes, this may lead to sub-optimal investment in settings with scarce resources.

What does this study add to the literature?

- We show that the volumes of normal and complicated deliveries in a facility are not aligned with its status as a basic or comprehensive emergency obstetric and neonatal care (BEmONC and CEmONC) facility in Burundi, a finding that also points to failures in the referral system.
- We show, using routine data that a subset of facilities can be identified with high numbers of normal and complicated deliveries that are very poorly staffed; together these 24/112 facilities manage 30% of all deliveries, 35% of complicated deliveries but have only 15% of available staff and could be prioritised for investment in the face of scarce resources.

What are the policy implications?

- This study shows how routine data might be better leveraged to support policy makers make decisions to improve efficiency and potentially effectiveness of human resource investments by demonstrating application of the approach to Burundi's EmONC network.

Declaration of interests

☒The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: