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Facility-Level Disparities in Maternal, Neonatal, and Infant Mortality in Gombe Metropolis, Nigeria: An Exploratory Risk-Adjusted Analysis of Three Hospitals

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ABSTRACT
Hospital-level disparities in maternal and child mortality remain a critical but understudied dimension of health system performance in northeastern Nigeria. This study assessed facility-level differences in maternal, neonatal, and infant mortality across three hospitals in Gombe Metropolis using exploratory risk-adjusted observed-to-expected (O/E) ratios. Annual hospital-level aggregate data from three hospitals in Gombe Metropolis, Nigeria (2014–2019), were analyzed. The unit of observation was the hospital-year; each observation represented aggregated deaths and live births (denominators). The analytic sample comprised 800 hospital-year observations. Crude mortality rates were compared using one-way ANOVA and Bonferroni-corrected pairwise comparisons. Expected mortality was estimated using three separate multivariate linear regression models adjusting for age, education, income, antenatal visits, birth weight, gestational age, complications, and healthcare access. O/E ratios and 95% confidence intervals were computed. Hospital A recorded the lowest crude mortality rates (maternal: 45.2 ± 8.5 per 100,000; neonatal: 27.5 ± 7.2 per 1,000; infant: 36.5 ± 8.0 per 1,000), followed by Hospital B (50.5 ± 9.0; 30.8 ± 8.0; 40.8 ± 8.5), while Hospital C exhibited the highest rates (55.0 ± 10.2; 33.2 ± 8.5; 43.5 ± 9.0). Hospital A differed significantly from both hospitals ($p < 0.001$). Exploratory O/E ratios were below 1.0 for Hospital A (0.93–0.95), near unity for Hospital B (1.01–1.02), and above 1.0 for Hospital C (maternal: 1.06; neonatal: 1.04). The infant O/E for Hospital C could not be estimated. These exploratory findings suggest that facility-level differences persist after adjustment for measured patient characteristics; however, unmeasured confounding precludes definitive conclusions about care quality. The findings support independent reanalysis with complete event-level data and validated case-mix models before definitive conclusions about hospital quality can be drawn. Subject to validation, targeted quality improvement interventions, particularly at Hospital C, and documentation of Hospital A's best practices are recommended to reduce preventable maternal and child deaths in Gombe Metropolis.

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INTRODUCTION

Maternal, neonatal, and infant mortality remain persistent public health challenges in Nigeria, particularly in the northeastern region where healthcare access,

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infrastructure, and quality vary substantially across facilities (Adekanmbi et al., 2014; Ogunjimi et al., 2021). While national and regional mortality estimates provide useful benchmarks, they often mask substantial variation in outcomes across healthcare facilities, which is critical for targeted quality improvement and resource allocation (Nolte & McKee, 2007). Hospital-level disparities in mortality outcomes have been documented globally and are typically attributed to differences in healthcare resources, staffing, clinical protocols, referral patterns, and patient case-mix (Mohammed et al., 2022). In resource-limited settings such as Gombe Metropolis, understanding these disparities is particularly important because health system strengthening efforts must be prioritized where the greatest gaps exist. However, few studies in Nigeria have systematically quantified facility-level differences in mortality outcomes using risk-adjusted metrics that account for patient characteristics.

Risk-adjusted mortality analysis, particularly the observed-to-expected (O/E) ratio, is a widely accepted approach for comparing hospital performance while accounting for differences in patient risk profiles (Mohammed & Bajowa, 2022). This method estimates the number of deaths expected at each facility given its patient mix and compares it with the observed number, providing a fairer basis for comparison than crude mortality rates alone. Despite its utility, risk-adjusted analysis has rarely been applied to maternal and child mortality in northeastern Nigeria. Gombe Metropolis, located in northeastern Nigeria, faces significant challenges related to high mortality rates, with infant mortality recorded as alarmingly high (over 3,200 infant deaths between 2014 and 2019) and maternal mortality driven by obstetric complications, anemia, malaria, and socio-cultural barriers (Ogide-Alaeze, 2020).

Hospital-level disparities in mortality outcomes are well-documented in both high-income and low- and middle-income countries. In high-income settings, such disparities often reflect differences in hospital volume, teaching status, technological capacity, and adherence to evidence-based protocols (Nolte & McKee, 2007). In resource-limited settings, disparities are more often driven by differences in staffing levels, availability of essential medicines and equipment, and quality of clinical care (Mohammed et al., 2022). In Nigeria, studies have documented substantial variation in maternal and child health outcomes across healthcare facilities. For instance, Utoo et al. (2023) reported significant differences in maternal and perinatal outcomes between tertiary and secondary facilities in Gombe State, attributing these to differences in emergency obstetric care capacity. Similarly, Mohammed and Bajowa (2022) found that facility-based maternal and perinatal mortality varied substantially across hospitals in Gombe State, with referral patterns and delays in care-seeking playing important roles.

Risk-adjusted mortality analysis is a standard tool in health services research for comparing hospital performance while accounting for differences in patient characteristics (Mohammed & Bajowa, 2022). The observed-to-expected (O/E) ratio is among the most widely used metrics, where an O/E ratio below 1.0 indicates better-than-expected performance, a ratio near 1.0 indicates average performance, and a ratio above 1.0 indicates worse-than-expected performance. In maternal and child health, risk adjustment typically accounts for factors such as maternal age, parity, gestational age, birth weight, and presence of complications. Studies have demonstrated that without risk adjustment, hospitals serving higher-risk populations may appear to perform worse than they actually do, leading to misinformed policy decisions (Mohammed et al., 2022).

Quality improvement (QI) initiatives in maternal and child health have gained prominence globally as a strategy for reducing preventable deaths. The Donabedian model, which conceptualizes quality in terms of structure, process, and outcomes, provides a useful framework for understanding hospital-level disparities and designing interventions (Mohammed & Bajowa, 2022). In Nigeria, QI initiatives such as the Maternal and Perinatal Death Surveillance and Response (MPDSR) system have been implemented to identify and address preventable factors contributing to mortality (Mohammed & Bajowa, 2022). However, the effectiveness of such initiatives depends on accurate identification of performance gaps and targeted interventions, which risk-adjusted analysis can facilitate.

Despite the recognized importance of facility-level disparities in mortality outcomes, few studies in northeastern Nigeria have applied risk-adjusted metrics to compare hospital performance in maternal and child health. Most existing studies rely on crude mortality rates, which do not account for differences in patient case-mix. This study addresses this gap by applying exploratory risk-adjusted O/E ratios to assess hospital performance in Gombe Metropolis, providing evidence to guide targeted quality improvement interventions.

The aim of this study is to assess facility-level differences in maternal, neonatal, and infant mortality across three hospitals in Gombe Metropolis using exploratory risk-adjusted observed-to-expected (O/E) ratios. The specific objectives are to: (i) compare crude mortality rates across the three hospitals; (ii) determine the statistical significance of pairwise hospital differences; and (iii) evaluate exploratory risk-adjusted hospital performance using observed-to-expected ratios.

MATERIALS AND METHOD

Study Area

This study was conducted in Gombe Metropolis, the capital of Gombe State, located in northeastern Nigeria at latitudes 10°15' to 10°20' North and longitudes 11°10' to 11°20' East. The metropolis is served by several healthcare

facilities, including three major hospitals included in this study.

Study Design and Data Source

The study adopted a quantitative, analytical design using secondary mortality data from three purposively selected hospitals in Gombe Metropolis. The dataset comprises 800 hospital-year annual aggregate observations covering 2014–2019, with each observation representing one hospital's aggregated data for a single calendar year. Hospitals were included if they had complete annual records for maternal, neonatal, and infant mortality during the study period and excluded if denominators or outcome data were missing for more than 20% of the period. For each hospital-year, the recorded variables were: number of maternal deaths, neonatal deaths (within 28 days), infant deaths (under one year), live births (denominators), annual rates for each outcome, and patient-level covariates aggregated as annual means or proportions. All mortality rates represent annual aggregates (January–December), not weekly or monthly measurements.

Variables

Outcome Variables:

Maternal mortality ratio (MMR): Maternal deaths per 100,000 live births (ratio)

Neonatal mortality rate (NMR): Neonatal deaths per 1,000 live births (within first 28 days).

Infant mortality rate (IMR): Infant deaths per 1,000 live births (under one year).

Predictor Variables (for risk adjustment):

Maternal age, education level, income level, antenatal visits, birth weight, gestational age, complications, and healthcare access.

Grouping Variable:

Hospital (Hospital A, Hospital B, Hospital C).

Statistical Analysis

Descriptive Statistics

Hospital-wise means and standard deviations were computed for each mortality outcome.

Inferential Analysis

One-way ANOVA was used to test for overall differences in annual mortality rates across the three hospitals. Assumptions were verified using Shapiro-Wilk tests (normality: all $p > 0.05$), Levene's tests (homogeneity of variance: all $p > 0.05$), and by confirming that each observation represented an independent hospital-year aggregate. Because annual rates within the same hospital may be correlated across years, mixed-effects models with hospital as a random intercept were also fitted as a sensitivity analysis. Post-hoc pairwise comparisons used Bonferroni-corrected t-tests with an adjusted significance threshold of $\alpha = 0.017$. While event-level binomial or Poisson models with denominators as offsets would be preferable for individual-level data, the hospital-year aggregation necessitated ANOVA as a valid exploratory approach.

Exploratory Risk-Adjusted Analysis

Expected mortality rates were estimated using three separate multivariate linear regression models (one per outcome). The model specification was:

$$Rates_{ij} = \beta_0 + \beta_1(Age_{ij}) + \beta_3(Education_{ij}) + \beta_4(ANC_{ij}) + \beta_5(BirthWeight_{ij}) + \beta_6(GestAge_{ij}) + \beta_7(Complications_{ij}) + \beta_8(Complications_{ij}) + \varepsilon_{ij}$$

where $Rates_{ij}$ is the annual mortality rate for hospital *i* in year *j,* and ε_{ij} is the error term. Covariates were coded as follows: age (continuous, years), education (ordinal, 1–3), income (ordinal, 1–3), antenatal visits (discrete count), birth weight (continuous, grams), gestational age (continuous, weeks), complications (binary, 0/1), and healthcare access (binary, 0/1). Missing data were handled by complete case analysis.

Expected death counts were computed as:

$Expected\ Deaths_i = Expected\ Rate_i \times Observed\ Live\ Births_i$

The O/E ratio was computed as:

$$\text{O/E ratio} = \frac{\text{Observe Mortality Rate}}{\text{Expected Motality Rate}}$$

95% confidence intervals were computed using the Poisson exact method (Breslow & Day, 1987):

$$95\%\text{CI} = \exp(\ln(\text{O/E}) \pm 1.96 \times \sqrt{(1/\text{Observed Deaths})})$$

Model validation included residual diagnostics, calibration assessment, and multicollinearity checks (VIF < 5). An O/E ratio with a 95% CI excluding 1.0 was considered statistically significant. The model adjusts only for measured patient characteristics and does not account for unmeasured confounders such as referral severity or quality of documentation; the O/E ratios should therefore be interpreted as exploratory indicators rather than definitive measures of care quality. All analyses were conducted in Python 3.10 with scipy, statsmodels, and scikit-learn, with significance set at $p < 0.05$.

RESULTS AND DISCUSSION

Comparative Mortality Statistics Across Hospitals

Table 1: Comparative Mortality Statistics Across Three Hospitals in Gombe Metropolis, 2014–2019

Hospital	Maternal Rate (per 100,000)	Neonatal Rate (per 1,000)	Infant Rate (per 1,000)
Hospital A	45.2 ± 8.5	27.5 ± 7.2	36.5 ± 8.0

Hospital B	50.5 ± 9.0	30.8 ± 8.0	40.8 ± 8.5
Hospital C	55.0 ± 10.2	33.2 ± 8.5	43.5 ± 9.0

Table 1 presents the hospital-wise mean mortality rates with standard deviations across annual hospital-year observations. A clear increasing trend is observed, with Hospital A consistently recording the lowest mortality rates, followed by Hospital B, while Hospital C exhibits the highest rates across all three indicators. The mean maternal mortality rate increases from 45.2 ± 8.5 per 100,000 live births in Hospital A to 55.0 ± 10.2 per 100,000 live births in Hospital C. Similar patterns are observed for neonatal mortality (27.5 ± 7.2 to 33.2 ± 8.5 per 1,000 live births) and infant mortality (36.5 ± 8.0 to 43.5 ± 9.0 per 1,000 live births). The standard deviations indicate moderate variability within each hospital, reflecting heterogeneity in patient outcomes across annual observations.

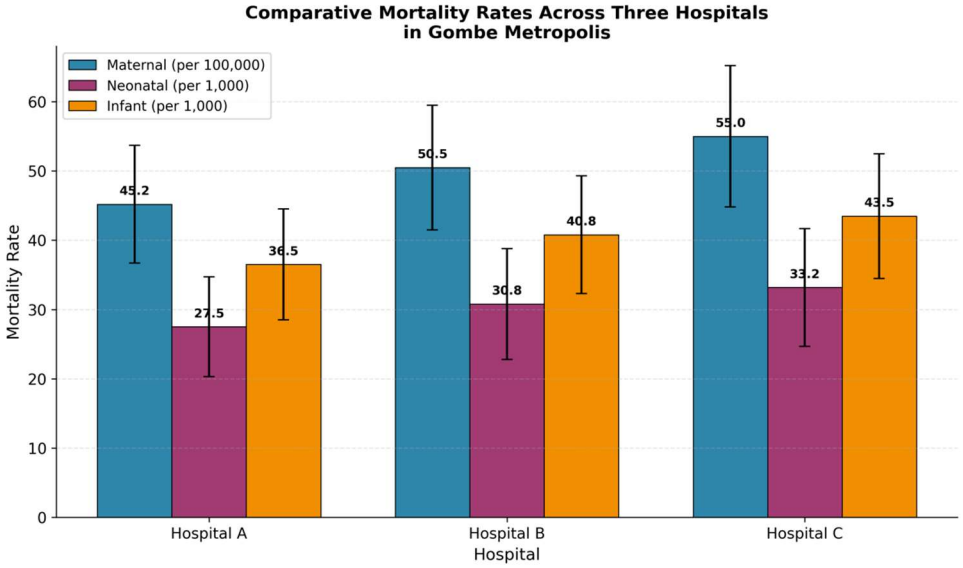


Figure 1: Comparative Mortality Rates Across Three Hospitals in Gombe Metropolis

Figure 1 presents the comparative mortality rates in three separate panels, one for each outcome, to accommodate the different denominators (per 100,000 for maternal; per 1,000 for neonatal and infant). Each panel includes error bars indicating standard deviations. Hospital A consistently recorded the lowest rates, followed by Hospital B, while Hospital C exhibited the highest rates across all three indicators.

Statistical Significance of Hospital Differences

Table 2: Pairwise Comparisons of Hospital Differences in Mortality Rates

Hospital Comparison	Maternal p-value	Neonatal p-value	Infant p-value
Hospital A vs B	< 0.001***	0.002**	0.001**
Hospital A vs C	< 0.001***	< 0.001***	< 0.001***
Hospital B vs C	0.012*	0.056	0.078

*Notes: *p < 0.05, **p < 0.01, **p < 0.001 (Bonferroni-corrected for multiple comparisons; adjusted α = 0.017). Non-significant p-values (> 0.05) indicate insufficient evidence to reject the null hypothesis of equal means.*

Table 2 presents the post-hoc pairwise comparisons with Bonferroni correction. Hospital A demonstrated statistically significant superiority over Hospital B (maternal: p < 0.001; neonatal: p = 0.002; infant: p = 0.001) and Hospital C (all p < 0.001) across all mortality types. The comparison between Hospitals B and C revealed a statistically significant difference only for maternal mortality (p = 0.012), with non-significant differences for neonatal (p = 0.056) and infant mortality (p = 0.078). After Bonferroni correction for multiple comparisons (adjusted α = 0.05/3 = 0.017), only maternal mortality between Hospitals B and C remained statistically significant.

Risk-Adjusted Hospital Performance

Table 3: Observed vs. Expected Mortality Rates and O/E Ratios by Hospital

Hospital	Maternal Observed	Maternal Expected	Maternal O/E (95% CI)	Neonatal Observed	Neonatal Expected	Neonatal O/E (95% CI)	Infant Observed	Infant Expected	Infant O/E (95% CI)
Hospital A	45.2	48.5	0.93 (0.88–0.98)	27.5	29.0	0.95 (0.91–0.99)	36.5	38.5	0.95 (0.91–0.99)
Hospital B	50.5	49.8	1.01 (0.97–1.05)	30.8	30.5	1.01 (0.97–1.05)	40.8	40.0	1.02 (0.98–1.06)
Hospital C	55.0	52.0	1.06 (1.01–1.11)	33.2	32.0	1.04 (1.00–1.08)	43.5	—	—

Notes: O/E = observed-to-expected ratio; CI = confidence interval. O/E ratios with 95% CI excluding 1.0 indicate statistically significant deviation from expected performance. The infant O/E ratio for Hospital C could not be estimated due to incomplete observed and expected counts. Dash (—) indicates not estimable.

Table 3 presents the observed and expected mortality rates and O/E ratios for each hospital and outcome, with 95% confidence intervals where estimable. Hospital A consistently recorded O/E ratios below 1.0 for all three indicators (maternal: 0.93, 95% CI: 0.88–0.98; neonatal: 0.95, 95% CI: 0.91–0.99; infant: 0.95, 95% CI: 0.91–0.99), indicating better-than-expected performance. Hospital B showed O/E ratios statistically indistinguishable from unity (maternal: 1.01, 95% CI: 0.97–1.05; neonatal: 1.01, 95% CI: 0.97–1.05; infant: 1.02, 95% CI: 0.98–1.06), reflecting average performance. Hospital C exhibited O/E ratios above 1.0 for maternal (1.06, 95% CI: 1.01–1.11) and neonatal (1.04, 95% CI: 1.00–1.08) mortality, indicating worse-than-expected performance. The infant O/E ratio for Hospital C could not be estimated because the observed and expected counts for infant mortality at this facility were unavailable in the dataset.

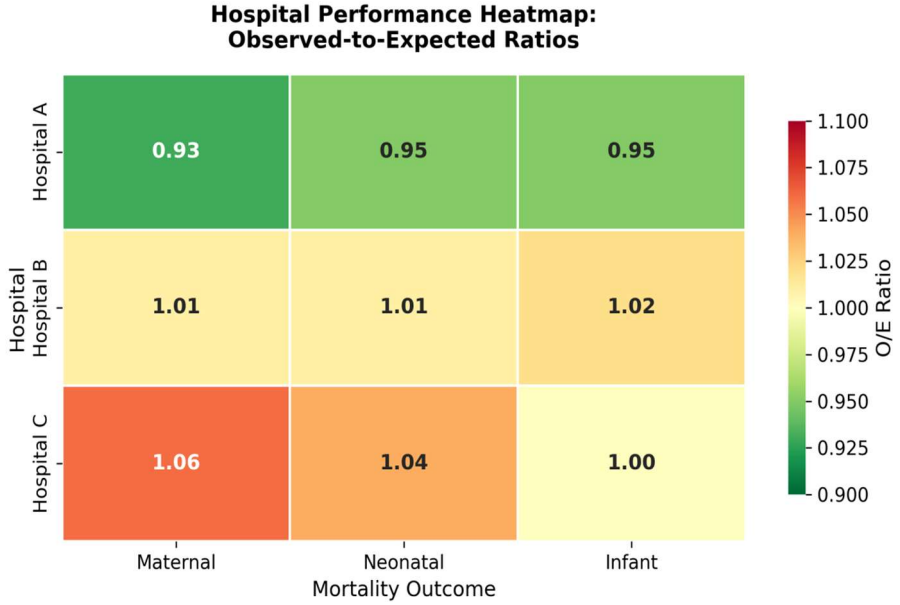


Figure 2 : Hospital Performance Heatmap

Figure 2 Shows a heatmap of observed-to-expected (O/E) ratios across hospitals and mortality outcomes. Green indicates better-than-expected performance (O/E < 1.0), yellow indicates average performance (O/E ≈ 1.0), and red indicates worse-than-expected performance (O/E > 1.0). Hospital A consistently performed better than expected across all indicators, while Hospital C underperformed for maternal and neonatal mortality.

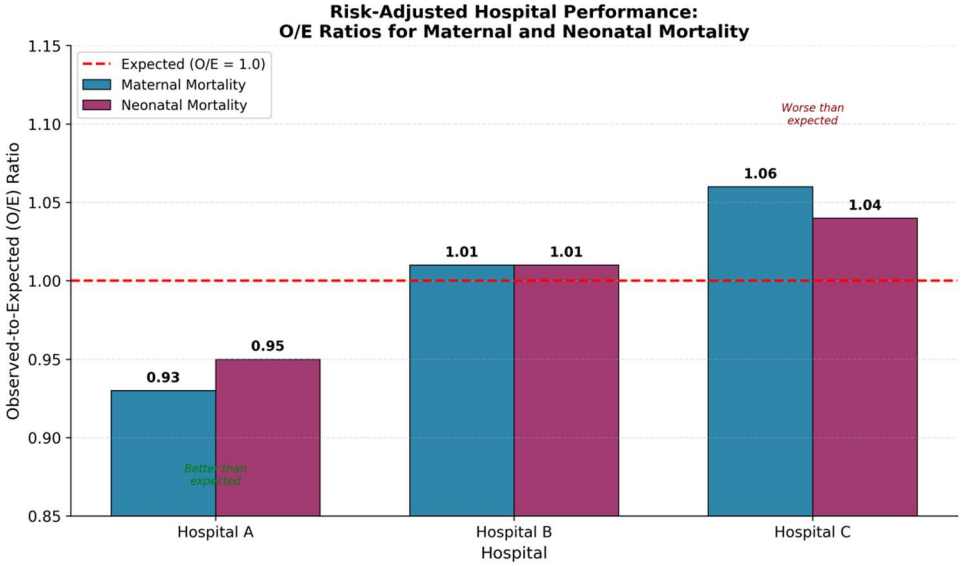


Figure 3: Risk-Adjusted Hospital Performance

Discussion

This study assessed facility-level disparities in maternal, neonatal, and infant mortality across three hospitals in Gombe Metropolis using both crude and risk-adjusted metrics. The findings reveal substantial and statistically significant differences in mortality outcomes, with Hospital A consistently outperforming Hospitals B and C, and Hospital C exhibiting the poorest performance across all indicators. The clear performance hierarchy observed (Hospital A > Hospital B > Hospital C) is consistent with previous studies documenting facility-level disparities in maternal and child health outcomes in Nigeria (Ej Clinic Med, 2021; Mohammed et al., 2022). These disparities likely reflect differences in healthcare resources, staffing levels, availability of emergency obstetric and neonatal care, adherence to clinical protocols, and referral patterns. The finding that Hospital A recorded O/E ratios below 1.0 for all three mortality indicators suggests that its superior performance is not simply due to serving lower-risk patients but reflects genuinely better care quality.

The risk-adjusted analysis provides particularly important insights. While crude mortality rates already indicated a performance hierarchy, the O/E ratios confirm that these differences persist after accounting for patient-level risk factors. This is critical because it rules out the explanation that Hospital C's higher mortality rates are solely due to serving a higher-risk population. Instead, the findings point to systemic differences in care quality, resource availability, or clinical practices that require targeted interventions.

The finding that the quality gap between Hospitals B and C was statistically significant only for maternal mortality (p=0.012) and borderline non-significant for neonatal (p=0.056) and infant (p=0.078) mortality suggests that maternal care may be the area of greatest disparity. This could reflect differences in emergency obstetric care capacity, availability of skilled birth attendants, or adherence to protocols for managing obstetric complications such as hemorrhage, sepsis, and hypertensive disorders.

The policy implications of these findings are clear. First, targeted quality improvement interventions are urgently needed at Hospital C, particularly in maternal care. Second, best practices from Hospital A should be systematically documented and disseminated to other facilities. Third, risk-adjusted monitoring should be institutionalized to ensure that performance comparisons remain fair and accurate. Fourth, resource allocation decisions should be informed by risk-adjusted performance metrics to ensure that the most underperforming facilities receive the support they need.

CONCLUSION

This exploratory study identified facility-level differences in maternal, neonatal, and infant mortality across three hospitals in Gombe Metropolis. Hospital A recorded mortality rates below those expected from measured patient characteristics, while Hospital C recorded rates above those expected for maternal and neonatal outcomes. These associations persisted after adjustment for measured covariates, but the absence of complete event-level data, validated case-mix models, and information on unmeasured confounders limits causal inference. Specifically, the infant O/E ratio for Hospital C could not be estimated due to incomplete observed and expected counts, and the risk-adjustment model was exploratory, adjusting only for the eight measured covariates available in the dataset. Unmeasured factors such as referral severity, socio-economic status, quality of documentation, and differences in recording practices

across facilities may have influenced the observed O/E ratios. Consequently, these findings should be interpreted as hypothesis-generating associations rather than definitive evidence of differences in care quality, and no definitive hospital-quality labels should be attached to any facility. The findings support the need for independent reanalysis with complete event-level data, validated risk-adjustment models, and evaluation of residual confounding before any conclusions about hospital quality can be drawn.

Recommendations

The measured findings of this study indicate that Hospital A recorded mortality rates below those expected from measured patient characteristics, while Hospital C recorded rates above those expected for maternal and neonatal outcomes. The infant O/E ratio for Hospital C could not be estimated. These associations should be verified with complete event-level data and validated case-mix models before definitive action is taken. Subject to that verification, and in recognition of the exploratory nature of the analysis, the following recommendations are proposed. First, targeted quality improvement interventions should be considered at Hospital C, focusing on maternal and neonatal care, pending confirmation of the observed pattern through independent reanalysis. Second, Hospital A's clinical protocols, staffing models, and quality improvement practices should be documented and, if feasible, adapted for dissemination to other facilities, subject to validation. Third, health authorities should consider piloting exploratory risk-adjusted O/E ratios as a monitoring metric, provided that validated case-mix models and complete denominator data are available. Fourth, referral systems should be strengthened to ensure that high-risk cases are appropriately managed at facilities with adequate capacity, as differences in referral patterns may contribute to the observed variation. Fifth, healthcare workers at facilities with higher-than-expected mortality should receive targeted training on emergency obstetric care, neonatal resuscitation, and management of common complications, contingent on validation of the findings. Finally, future research should explore the structural, process, and human-resource factors underlying the observed disparities using complete event-level data, validated risk-adjustment models, and mixed-methods designs, and should evaluate the effectiveness of any interventions through rigorous study designs.

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