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Original Research Article

Assessing the Effectiveness of Oral Cholera Vaccine (OCV) in Reducing Cholera Mortality Rates: Population-Based Study in Selected Cholera Hotspot Zones of Lusaka District

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Abstract: ***Introduction*:** Cholera is recurrent in Zambia particularly in Lusaka district where outbreaks occur with regularity, typically during the rainy season. Despite the progress in improving Water, Sanitation, and hygiene (WASH) interventions, outbreaks are still persistent. This research aimed at assessing the effectiveness of Oral Cholera Vaccine in reducing cholera related mortality in the hotspot zones of Lusaka District, with a goal to inform public health strategies for cholera prevention and control. ***Methods*:** Retrospective cross-sectional study from April 2022 to April 2024, among 385 reported cholera cases meeting clinical/laboratory definitions in high-risk sub-districts (Kanyama, Matero, Mandevu, Chawama) on the effectiveness of the Oral Cholera Vaccine. Data was collected from health facilities, and surveillance databases. Descriptive statistics, and multivariable regression analysis were performed to evaluate the association between the independent variables and the outcome at a P value less than 0.05 with 95% confidence interval (CI). ***Results*:** Among the 385 cases reported, only 59.2% of the participants were vaccinated. Vaccination reduced cholera severity (coefficient=0.815, p<0.001), while hospitalization worsened outcomes (-0.193, p<0.001). Longer hospital stays improved recovery (0.108, p<0.001). Older age (0.002, p=0.020) and male gender (0.066, p=0.026) were linked to better outcomes. Access to clean water (-0.051, p=0.099) and improved water sources (-0.077, p=0.001) reduced the risk of disease. Sanitation and geographic location had no significant effects. ***Conclusion*:** OCV had a significant reduction on mortality and disease severity during cholera outbreaks in the hotspot zones. The results affirm the role of OCV in cholera prevention and emphasize the need to expand vaccine coverage, improve WASH infrastructure, and tailor healthcare interventions based on demographic differences.

Keywords: Cholera, Oral Cholera Vaccine (OCV), Multivariable Analysis, Water Sanitation and Hygiene (WASH), Zambia.

INTRODUCTION

The World Health Organization (WHO) has estimated that between 1.3 to 1.4 million cases of cholera occur each year, resulting in 21,000 to 143,000 deaths globally (WHO, 2023a). Cholera is caused by the bacterium *Vibrio cholerae,* which leads to an acute diarrheal disease characterized by severe dehydration, electrolyte imbalances, and, if untreated, can rapidly lead to death. Cholera remains a significant public health threat, particularly in regions with inadequate sanitation, limited access to clean water, and poor hygiene practices. The disease is mainly spread through faecal-oral transmission, with contaminated food and water being the major modes of transmission (Harris *et al*., 2012).

Despite some progress in the provision of clean water and sanitation (WASH), cholera remains a

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significant global health threat, particularly in developing nations. The persistence of cholera in developing regions also underscores the need to tackle the social conditions that allow its transmission, including insufficient infrastructure provision, gaps in access to safe drinking water and the health education of vulnerable communities. An integrated, multi-sector approach that combines improved WASH interventions with vaccination campaigns and strengthened public health systems is vital for reducing cholera incidence and saving lives in affected regions. (WHO, 2023A).

In Zambia, cholera remains a recurrent public health threat, especially in Lusaka District in Lusaka Province. The disease frequently resurfaces during the rainy season, causing seasonal outbreaks that traumatize communities and overwhelm the health system. Lusaka, the capital and most populous city of Zambia, is prone to cholera based on socio-economic and environmental vulnerabilities. Informal structures are often connected to a rudimentary sewer system that drains directly into rivers used for drinking and bathing, one of the primary causes of a vicious cycle of recurring disease outbreaks. Residents often rely on unsafe water sources in crowded informal settlements, as they are prone to contamination from human fecal matter in the rainy season, triggering the spread of the *Vibrio cholerae* bacterium (World Health Organization (WHO, 2023a).

Cholera has a negative social and economic component, with life and illness causing an economic impact on families and communities. Preventive measure such as improving water sanitation and hygiene (WASH) are critical in preventing recurrent cholera outbreaks but are often insufficient due to funding gaps and poor infrastructure. Direct vaccination against cholera with oral cholera vaccines is increasingly recognized as a critical tool for cholera control when used to complement other preventive and control measures in cholera-endemic areas (WHO, 2023a).

Studies have shown that OCVs can reduce cholera incidence and that cholera vaccines have an efficacy in reducing cases by 50-85% in the first two years following vaccination (WHO, 2023a). Although the short-term efficacy of oral cholera vaccines has been established, little is known about their long-term effectiveness.

This study sought to provide evidence and fill a knowledge gap on OCV's effectiveness in hotspot zones for cholera prone areas in Lusaka, with a view to informing public health policy and contribute to global evidence on sustainable cholera control.

METHODS AND MATERIALS

Study Design

This study used a retrospective cross-sectional design to interpret records of people who received OCV and those who did not and to compare incidence of cholera and mortality between the individuals. The period of assessment was from the time of the first vaccination from April 2022 up through April 2024.

Study Population

The study population included cholera cases and deaths reported to the Ministry of Health from health facilities and communities in Lusaka district hotspot zones between April 2022 and April 2024. Eligible cases met the standard clinical and or laboratory definitions of cholera as established by the ministry of health. The study included both clinical and community data, as well as demographic and epidemiological information.

Sample Size

The minimum required sample required for the study was calculated using the standard formula for proportion estimates at a 95% confidence interval, with a 5% margin of error and an assumed prevalence of 50% (Lee *et al*., 2020), yielding a sample size of 385.

Sampling Strategy

Random sampling technique was used to collected data from the cases recorded in the hotspot zones.

Data Ccollection

Data collection methods included extracting vaccination status data from records and identifying individuals who had received the OCV. Outcome data on cholera incidence and mortality were collected from health records and from public health surveillance databases. Age, sex, socioeconomic status, access to clean water and sanitation facilities were also collected as potential confounders.

Data Aanalysis

Data was entered and stored in Microsoft excels and exported to Stata version 14.2(stataCorp), College station, Texas, USA) for analysis.

Descriptive analysis was performed in Microsoft excel to summarize characteristics of vaccinated and unvaccinated groups. Categorical variables, chi square tests were used, and logistic regression modelling to calculate coefficients with a statistical significance set at $p < 0.05$.

RESULTS

A total of 385 observations of cholera cases observed in the hotspot zones of Lusaka district from April 2022-April 2024 were employed in this study. Each of these cases has the details on the variables of age, gender, zone, vaccinated or not, whether hospitalized and how long, access to clean water and what type of sanitation facilities the patients were using.

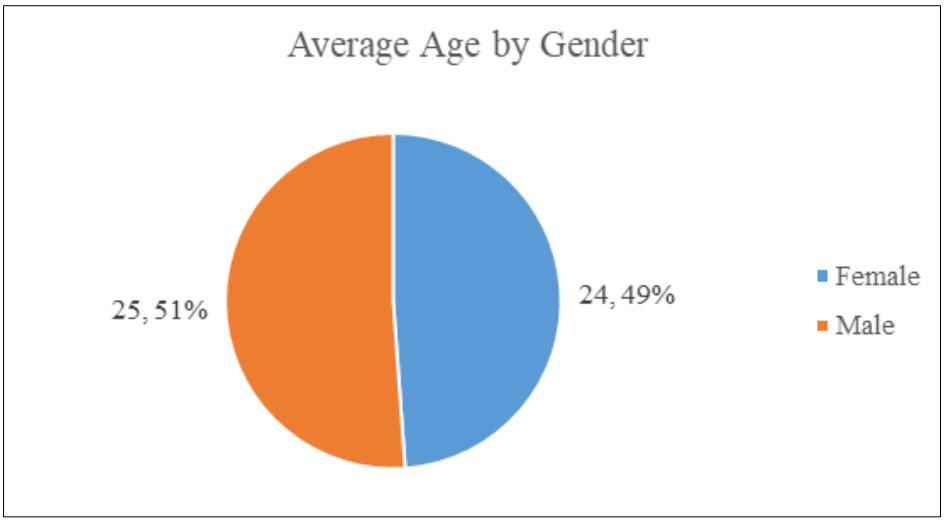

Figure 1: Proportion of age by gender

Figures 1 shows proportions of age by gender. The gender distribution was nearly equal, with 51% male and 49% female participants with the mean age of 25 years (SD = 15), reflecting a broad representation of both younger and older individuals.

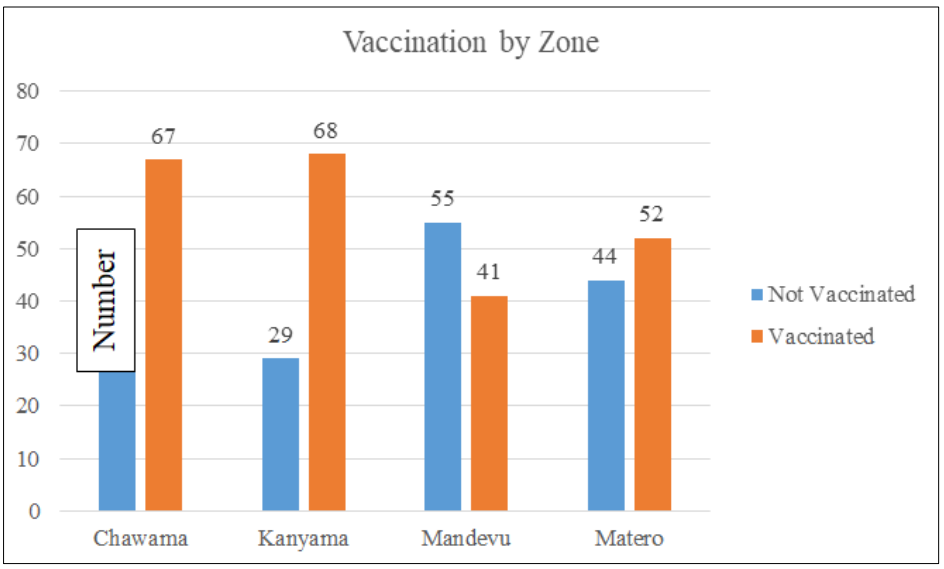

Figure 2: Vaccination status by zone

Figure 2, Out of the 385 participants in the study, 59% (228 individuals) received at least one dose of the oral cholera vaccine, while 41% (157 individuals) were not vaccinated. The study also tracked vaccination coverage across different geographic zones, revealing varying levels of vaccine coverage. The zone with the highest vaccination coverage was Kanyama 68/228 (29.8%) followed by Chawama 67/228 (29.4%), Matero 52/228 (22.8%) and Mandevu 41/228 (18%) respectively. These differences in vaccination coverage across the zones may reflect various factors such as access to healthcare services, community awareness, or local vaccination campaigns. Understanding these discrepancies is important, as it can help target future vaccination efforts and ensure that underserved areas receive the necessary resources to improve vaccine uptake and protect the population from cholera outbreaks.

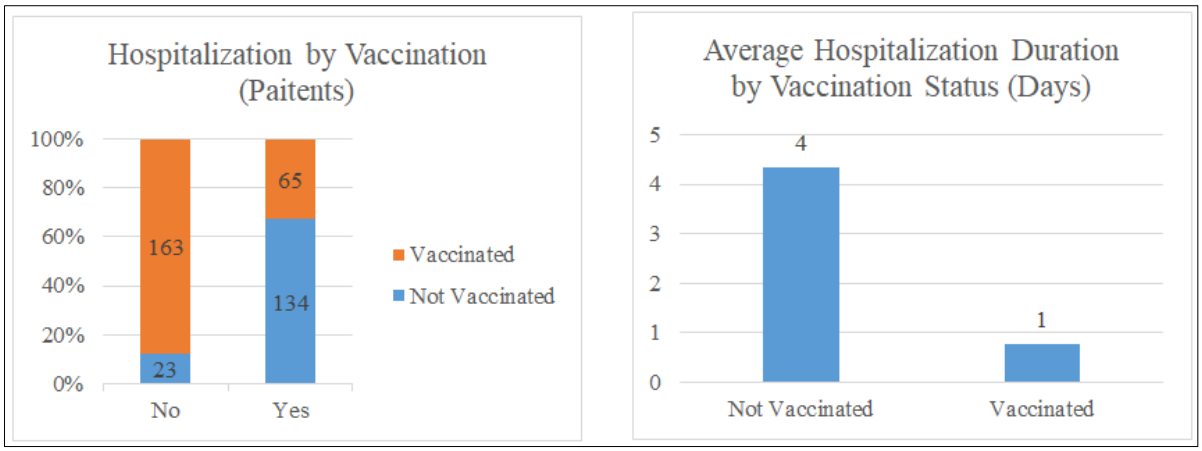

Figure 3: Hospitalization status and average duration of hospitalization by the vaccination status

Figure 3, among those hospitalized, the data revealed a significant difference in the duration of hospitalization between the vaccinated and unvaccinated groups. The average duration of hospitalization for unvaccinated individuals was 4 days, while vaccinated individuals had an average of just 1 day. This finding highlights the protective effect of the vaccine, as there were few hospitalisations among vaccinated individuals and had short hospital stay.

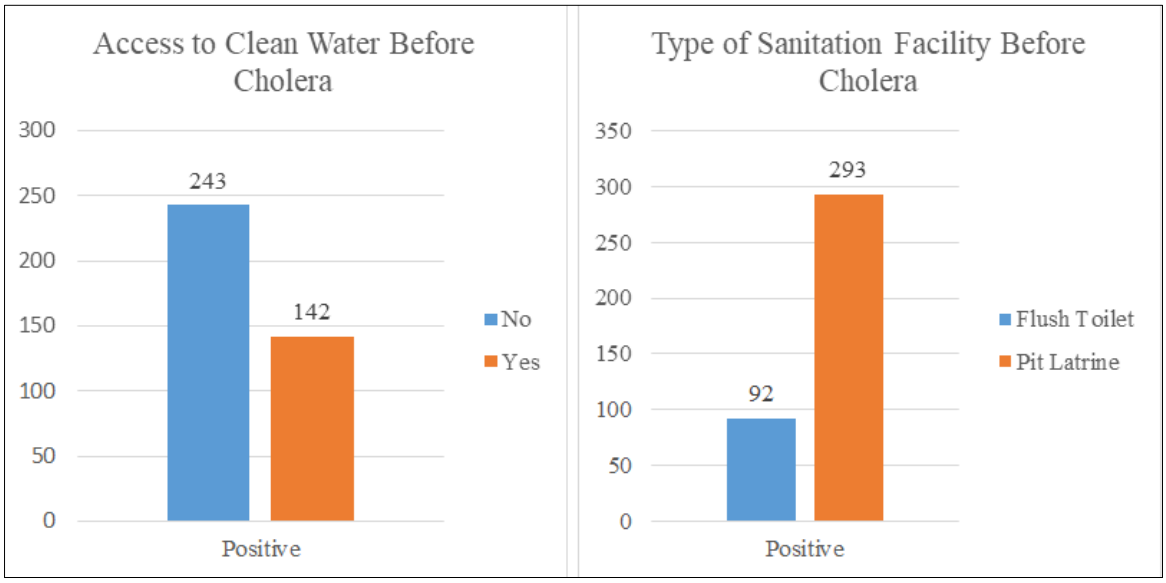

Figure 4: Cholera cases by access to clean water and usage of sanitation facilities

From figure 4, the participants were contact traced to determine their access to clean water. The results showed that 63% (243/385) of participants had no access to clean water. Lack of access to clean water, can be a key factor to cholera transmission and control. Further, the study also looked at sanitation practices of the participants. While the majority 76% (293/385) of the population still used pit latrines (a form of traditional sanitation), only a quarter of the population (24%) was connected to flush toilets. In Zambia's peri-urban and rural areas, pit latrines represent a popular form of sanitation, but these latrines can be easily contaminated.

Table 1: Number of recoveries and mortalities by vaccination status

2 X 2 Table	Recovery	Deceased	Totals
Vaccinated	222	6	228
Unvaccinated	72	85	157
Totals	294	91	385

Table 1 findings were that a total of 294 cholera patients (59%) recovered, whereas 91 patients (41%) died, giving rise to case fatality ratio (CFR) of 23.46%. The relatively high CFR reflects the devastating impact of cholera, especially in areas with limited healthcare and sanitation systems. The differences in mortality rates

between vaccinated and unvaccinated subjects were significant. Those who had not been vaccinated had much higher mortality rate and made up 93% of the deaths, against 7% from vaccinated people. This striking difference highlighted the role of the oral cholera vaccine in protecting against severe disease and death.

Table 2: Coefficient of determination

R^2	0.5685 (56.85%)
r	0.7539 (75.39%)
P>0.05	0.003

Results in table 2 revealed R^2 of 0.5685 as a goodness of fit with, meaning that around 56.85% of the variance in recovery outcome was been explained by the factors included in the model. The implication of this is that although there may be other significant factors at play, over half of the variance in why some people recovered better than others could be explained with these specific variables.

Table 3: Logistc regression Analysis: Association between outcome with Independent Variables

Variable	Coefficient	Std. Err	z-Statistic	p-Value	95% CI
Age	0.0024496	0.0010503	2.33	0.020	.0003843 .0045148
Gender	0.0660414	0.0295224	2024	0.026	.0079911 .1240916
Zone	0.0095639	0.0146318	0.65	0.514	-.0192068 .0383346
Vaccination Status	0.8149623	0.0410652	19.85	0.000	.7342155 .8957091
Hospitalization	-0.1927465	0.0518116	-3.72	0.000	-.2946243 -.0908688
Hospitalization Duration	0.1083706	0.0103826	10.44	0.000	.0879552 .128786
Access to Clean Water	-0.0512922	0.0310012	-1.65	0.099	-.1122501 .0096657
Sanitation Facilities	-0.0151943	0.034424	-0.44	0.659	-.0828825 .0524939
Water Source	-0.0773805	0.022279	-3.47	0.001	-.121188 -.033573

The logistic regression in table 3 shows the strongest determinants of the outcomes among all cases recored;

Age

- The output results for all independent variables showed that for every one year increase in age while holding all independent variables constant, older individuals will have a better recovery rate as compared with the younger individuals, with a P-value of 0.020 which is less than 0.05 which is statistically significant. This indicates that age is an important factor in recovery.

Gender

- The positive coefficient for gender indicates that being male is associated with a higher recovery rate. The males are more likely to recover from cholera as compared to females. The **p-value** of 0.026 shows that this relationship is statistically significant at the 5% level, reinforcing the importance of gender as a factor in recovery.

Vaccination status

- The positive coefficient for the vaccinated status indicates that the vaccinated individuals had a high recovery as compared to the not vaccinated with a p-value of 0.000 which is less than the 0.05 hence being statistically significant. This explains the critical role vaccination had in recovery of cholera patients.

Hospitaliztion

- The negative coefficient for the hospitalized individuals suggests that, those hospitalized had a poor recovery, with a calculated p-value of 0.000 which is less than the 0.05 at 95% confidence interval hence making it statistically significant

Hospitalization Duration

- The coefficient for hospitalization duration was positive, indicating that individuals who had prolonged hospitalization tend to recovery compared with a shorter hospitalization duration. The 0.000 p-value which is smaller than the 0.05 at 95% confidence interval showing that it is statistically significant.

Access to Clean Water

- The negative coefficient for water source indicates that bad access to clean water is associated with a bad outcome (death) Being statistically significant showing that p-value is less than 0.05 at 95% confidence interval with the p-value of 0.000

Zone, Water Sources and Sanitation Facility

- Being a residentt in a particular zone, availability of clean water and utilization of a specific sanitation facility does not have any significant effect on the outcome of the patient at 95% confidence having p-values more than 0.05.

Table 4: Chi-square test: association between vaccination status and recovery (outcome)

Outcome	Vaccination Status		Total
	0	1	
0	85	6	91
1	72	222	294
Total	157	228	385

Pearson chi2(1) = 136.6675 Pr = 0.000
likelihood-ratio chi2(1) = 149.0138 Pr = 0.000
Cramér's V = 0.5958

Table 4 Pearson's chi square test show a test statistics of 136.67, degree of 1 indicates that being vaccinated was associated with better outcome (recovery) compared to the non-vaccinated group at a p-value at 0.000 which was less than the significance level (0.05) hence being statistically significant. Cramér's V of 0.5958 indicating that the status of vaccination was one of the most contributing factors for outcome of cholera positive patients.

DISCUSSION OF THE RESULTS

These findings highlight a range of interesting factors that are strongly associated with health outcome (recovery) and offer insight into potential areas for intervention and policy development. Age, gender, vaccination status, hospitalization, duration of hospitalization and having access to clean water particularly emerged as significant predictors of health outcomes.

A key finding is the positive correlation of vaccination status with health outcomes. People who were vaccinated scored on health outcomes well above those who were unvaccinated, showing the value of vaccination not just in the prevention of disease but for the overall health of the general population. This is consistent with the literature reporting vaccines are significant contributors to burden reduction of infectious diseases, and health overall (Sridhar *et al*., 2018). The well-established impact of vaccination programs on the incidence of preventable disease, coupled with global public health challenges, shows the need for continued investment in vaccination (WHO, 2020).

Age proved to be another important predictor of health outcomes. Older participants were more likely to report health outcomes that I would consider more favorable, which might be counter intuitive at first, since aging is associated with poor health. But that finding could just as easily reflect a cohort effect that older adults have had better access to medical information over the decades or that older people in the study have better managed their health and achieved better outcomes. In fact, it is found that older population have more frequent contacts with the healthcare systems, consequently the health care system potentially provides more prevention and management care that potentially associate with good health outcomes (Fried *et al*., 2011).

Other key determinants were age and sex, where men had improved health outcomes compared to women. This may reflect differences in health-seeking behavior or access to primary sources of health care providers or it may represent more fundamental aspects of culture impacting health-related agency and the need to seek consultation for resolution of health issues. It is known that different socio- and lifestyle risk and health services patterns reflect in better health outcomes among men rather than women (Barker *et al*., 2006). Its generalizability is limited, however, as it can vary by health care setting and study population.

A major finding is the negative association of outcome and hospitalization. Those who had been hospitalized were even more likely to report having poor health outcomes, an association likely explained by the severity of the illnesses that would have needed to have been serious enough to require hospitalization. Hospitalization is often a proxy for severe comorbidities, which fits with the notion that patients who were able to be admitted to hospitalization are typically in a more severe state (Jha *et al*., 2012). But it is important to note that the length of stay was positively associated with health outcomes, meaning that those who stayed longer may have received more intensive treatments and been more likely to improve. Given that increased burden of illness has been shown to lead to worse health outcomes, our overall findings cannot be attributed to patients who live longer tend to receive more care, which can itself improve the health of patients with less severe illnesses (O'Hare *et al*., 2012).

Finally, the data indicating a negative association between access to clean water and different health outcome measures suggests the obvious: the link between the environment and public health. People with less access to clean water have poorer health outcomes. This is aligned with global evidence of water quality being associated with increasing gastro intestinal infections (Prüss-Üstün *et al*., 2008). The absence of access to sanitation and potable water is still an enormous global issue, especially in economically developing nations, as well as in rural regions without any functioning water infrastructure or clean water systems. It requires concerted efforts to upgrade water infrastructure and sanitary facilities in underdeveloped areas (Hunter *et al*., 2010).

CONCLUSION

This study sought to evaluate the effectiveness of OCV in reducing mortality and disease severity in selected cholera hotspots of Lusaka from April 2022 to April 2024. The findings provide strong evidence that OCV plays a crucial role in mitigating cholera related deaths and reducing the severity of the disease among vaccinated individuals.

Additionally, the study highlights the importance of expanding vaccination coverage, improving sanitation infrastructure, and strengthening public health interventions to further reduce cholera outbreaks.

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