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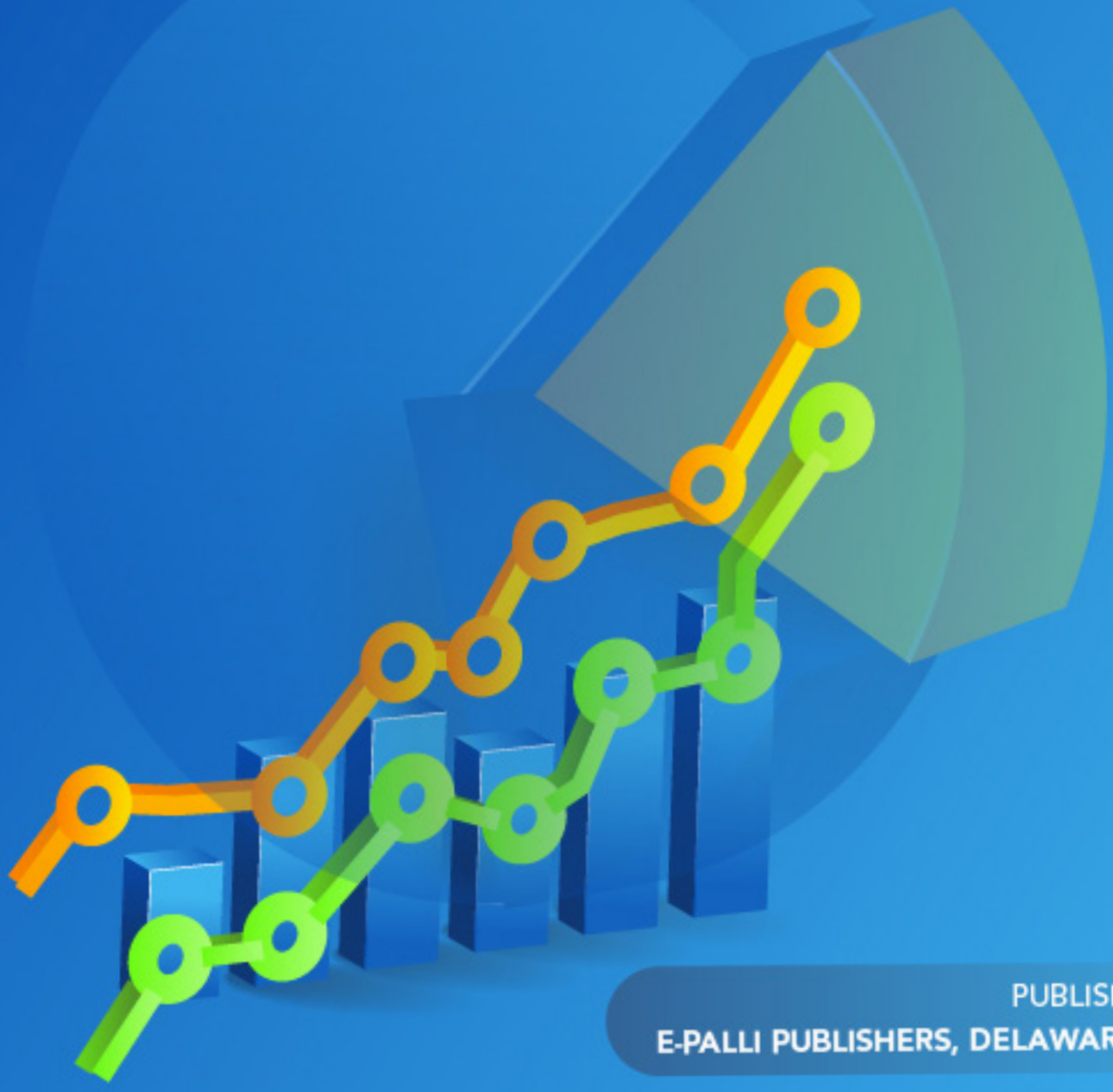

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Time-to-Treatment and Patient Survival in Ghana: A Kaplan Meier Evaluation of Delays in Clinical Intervention

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ABSTRACT

In Ghana's healthcare system, treatment delays continue to be a major problem that negatively impacts clinical results in a variety of illness categories. There are still few thorough survival analyses looking at the connection between time-to-treatment and mortality risk in the Ghanaian context, despite mounting data worldwide. The purpose of this study is to assess the relationship between treatment delay categories and patient survival outcomes at tertiary health facilities in Ghana using the Kaplan-Meier (K-M) estimator and log-rank test. A retrospective cohort of 1,240 patients who were admitted between 2018 and 2022 to Komfo Anokye Teaching Hospital and Korle-Bu Teaching Hospital was examined. Three delay groups were created by stratifying patients into early intervention (< 6 hours), moderate delay (6 to 24 hours), and late intervention (> 24 hours). Kaplan-Meier survival curves were constructed and pairwise comparisons performed using the log-rank test (significance level: $p<0.05$). Adjusted Cox proportional hazards models controlled for age, sex, disease severity, comorbidities, and socioeconomic status. Significant survival differences were observed across delay categories (log-rank $\chi^2=47.3$, $p<0.001$). The 30-day survival probability was 91.4% for early intervention, 78.6% for moderate delay, and 61.2% for late intervention groups. Cox regression confirmed that late intervention conferred a 2.8-fold increase in hazard of death (HR=2.81, 95% CI: 2.03-3.89, $p<0.001$) compared to early treatment, after controlling for covariates. In Ghana, treatment delays longer than 24 hours are significantly linked to lower survival rates for hospitalized patients. There is an urgent need for policy initiatives that focus on community health literacy, emergency triage procedures, and referral system efficiency.

INTRODUCTION

In Ghana, hospitalized patients' survival rates are strongly correlated with treatment delays beyond 24 hours. Policy measures that emphasize emergency triage protocols, community health literacy, and the effectiveness of the referral system are desperately needed.

There are three levels to Ghana's healthcare system: primary, secondary, and tertiary. Complex and critical cases are ultimately referred to the two major tertiary institutions, Komfo Anokye Teaching Hospital (KATH) in Kumasi and Korle-Bu Teaching Hospital (KBTH) in Accra. These institutions play crucial roles, but they are frequently overburdened by demand that surpasses capacity, which causes systemic delays at the point of service (Asante et al., 2017; Kyei-Nimakoh et al., 2017). At the community level, delayed health-seeking behaviour driven by financial constraints, geographical remoteness, and traditional health beliefs further compounds the challenge of timely intervention (Awini et al., 2020).

A strong non-parametric framework for estimating the likelihood of survival over time across exposure groups is provided by survival analysis, and specifically the Kaplan-Meier (K-M) technique (Kaplan & Meier, 1958). In contrast to straightforward proportional comparisons, the K-M estimator produces unbiased survival probability estimates by taking censored observations patients who are lost to follow-up or who survive over the study period—into consideration. It allows for statistically rigorous comparisons of survival distributions between groups when used with the log-rank test (Peto et al., 1977). The K-M technique is still underutilized in the assessment of treatment delays in the West African environment, despite its extensive use in cardiovascular and oncology studies worldwide.

In order to close this gap, this study evaluates the effect of treatment delays on patient survival probability at two significant tertiary institutions in Ghana using Kaplan-Meier survival analysis. Our specific objectives are to: (1) characterize the distribution of treatment delays among admitted patients; (2) estimate survival probabilities across specified delay strata; (3) test for statistically significant differences in survival between groups; and (4) use adjusted Cox proportional hazard models to identify independent predictors of mortality. The results are meant to guide hospital management practices and national health policy in an effort to lower avoidable fatalities linked to postponed care.

LITERATURE REVIEW

Global Evidence on Treatment Delays and Survival

In high-income settings, the correlation between time to treatment and clinical outcomes has been well documented. Emergency cardiology guidelines for acute myocardial infarction (AMI) have been influenced globally by the golden hour idea, which states that reperfusion therapy started within 60 minutes of symptom onset significantly

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reduces infarct size and mortality (McNamara et al., 2006; Nallamothu et al., 2007). The neurological necessity of thrombolytic therapy within 4.5 hours of ischemic onset is also encapsulated by the term "time is brain" for stroke (Lees et al., 2010). The Surviving Sepsis Campaign's three-hour bundle, which requires blood cultures, lactate measurement, and antibiotic initiation within three hours, has been shown in numerous randomized and observational trials to consistently reduce mortality in sepsis care (Rhodes et al., 2017).

In order to quantify these connections, Kaplan-Meier analyses have proved essential. Using K-M curves on a sample of more than 49,000 sepsis patients, Seymour et al. (2017) showed that survival probability decreased monotonically with each extra hour of antibiotic delay. K-M estimate was also utilized by Girotra et al. (2014) to show that hospitals with quicker median times to defibrillation had far greater survival-to-discharge rates. Together, these studies highlight how useful time-event analyses are for operationalizing treatment delay as a changeable survival factor.

Mundia I etal (2024) opined that, child mortality rate serves a key health indicator for any country and to accelerate progress towards reaching Sustainable Development Goal 3 by 2030, it is essential to understand the factors influencing under-five child mortality (UFCM), taking into account all potential confounding variables and effect modifiers.

Treatment Delays in Sub-Saharan Africa

A unique set of circumstances shapes the epidemiology of treatment delay in sub-Saharan Africa. In a systematic review, Dare et al. (2015) identified three phases of delay: system delay (time from diagnosis to treatment), provider delay (time from initial contact to diagnosis), and patient delay (time from symptom recognition to health-seeking). Each phase independently contributed to unfavorable outcomes. Over 60% of surgical emergency patients in Nigeria presented more than 48 hours after the onset of symptoms, according to Nnoli et al. (2019), and late presentation was linked to a noticeably increased 30-day mortality. Similar results have been documented for severe injuries in Kenya (Nantulya & Reich, 2002) and obstetric emergencies in Tanzania (Maaløe et al., 2012).

Asante et al. (2017) reported that the median door-to-needle time at KBTH for AMI patients significantly exceeded international benchmarks, while Kyei-Nimakoh et al. (2017) found that delays in receiving tertiary care significantly increased maternal mortality attributable to hemorrhage and eclampsia in Ghana. This work fills crucial evidence vacuum since, despite these isolated findings, no thorough survival analysis utilizing K-M technique has looked at treatment delays across many illness categories at Ghana's tertiary facilities.

Statistical Foundations: Kaplan-Meier and Cox Regression

The Kaplan-Meier product-limit estimator was introduced by Kaplan and Meier (1958) as a method for estimating the survival function from life-time data in the presence of censoring. Given survival times $t_1 < t_2 < ... < t_k$ for k distinct event times, the K-M estimator at time t is given by

$$S(t) = \prod_{\{t_i \le t\}} \left(1 - \frac{d_i}{n_i}\right)$$

where d_i is the number of events and n_i the number at risk at time t_i. This estimator is particularly suited to observational hospital data where follow-up durations vary across patients (Bland & Altman, 1998).

The null hypothesis that survival functions are equal across groups can be tested non-parametrically using the log-rank test, which was developed by Mantel (1966) and expanded by Peto et al. (1977). It is most effective when hazard ratios are proportionate and gives each time point equal weight. For multivariable adjustment, the Cox proportional hazards model (Cox, 1972) expresses the hazard function as $h(t|X) = h_0(t)\exp(\beta X)$, where $h_0(t)$ is the baseline hazard and β the vector of log hazard ratios for covariates X. The semi-parametric nature of the Cox model requiring no assumption about the shape of $h_0(t)$ makes it ideal for heterogeneous clinical populations.

MATERIALS AND METHODS

Study Design and Setting

Using medical records from Korle-Bu Teaching Hospital (KBTH), Accra, and Komfo Anokye Teaching Hospital (KATH), Kumasi, from January 2018 to December 2022, this study used a retrospective cohort design. With almost 2,000 beds, KBTH is the biggest hospital in Ghana, and KATH is the main tertiary referral facility for the Ashanti Region. Time-stamped admission, triage, and clinical intervention data are kept in structured medical record systems at both facilities.

Study Population and Eligibility Criteria

All adult patients (≥18 years) diagnosed with acute cardiovascular events, sepsis, traumatic injuries, and serious infectious infections and hospitalized via emergency or in-patient pathways were taken into consideration for inclusion. Patients who died within an hour of arrival (precluding meaningful delay classification), patients whose records lacked complete outcome documentation, patients transferred from other facilities where initial treatment had already begun, and patients with missing time-to-treatment data were all excluded. 1,240 patients made up the final analytic cohort once these criteria were applied.

Exposure Definition: Treatment Delay Categories

The time (in hours) between a patient's presentation at the emergency room and the first definite clinical intervention (such as medication therapy, surgery, or procedure-specific intervention) was referred to as the "time-to-treatment." Based on established clinical thresholds and prior literature, patients were stratified into three delay categories: Group A: Early Intervention (<6 hours, n=412); Group B: Moderate Delay (6-24 hours, n=489); and Group C Late Intervention (>24 hours, n=339).

Outcome

All-cause in-hospital mortality within 30 days of admission was the main outcome. Censored at the time of discharge or on day 30, whichever came first, were patients who were still alive after 30 days or who were released before 30 days without a documented death.

Covariates

Covariates included in adjusted analyses were: age (continuous, years); sex (male/female); disease category (cardiovascular, sepsis, trauma, infectious); admission severity score (mild, moderate, severe, based on WHO triage criteria); number of comorbidities (0, 1, ≥2); socioeconomic status proxy (National Health Insurance Scheme (NHIS) enrolment: yes/no); and hospital site (KBTH/KATH).

Statistical Analysis

Using means ± standard deviation (SD) for continuous variables and frequencies (%) for categorical variables, descriptive statistics summarized baseline characteristics by delay group. Chi-squared tests (categorical) and one-way ANOVA (continuous) were used to evaluate group differences. For every delay group, Kaplan-Meier survival curves were created, and Greenwood's algorithm was used to calculate the 95% confidence bands. The three groups' survival distributions were compared using pairwise log-rank tests, with Bonferroni correction used to keep the family-wise error rate at 0.05. Cox proportional hazards models, both adjusted and unadjusted, were fitted, with delay group serving as the main exposure. Schoenfeld residuals were used to confirm proportional hazards assumptions.

The survival, survminer, and ggplot2 packages were used in R version 4.3.1 for all studies. The threshold for statistical significance was established at $p<0.05$.

Ethical Considerations

The Institutional Review Boards of both hospitals and the Ghana Health Service Ethics Review Committee (GHS-ERC: 025/09/23) granted ethical approval. Individual patient consent was not required because the study entailed the retrospective examination of secondary data that had been anonymized. Ghana's Data Protection Act (2012) was followed in all data handling.

RESULTS AND DISCUSSION

Baseline Characteristics

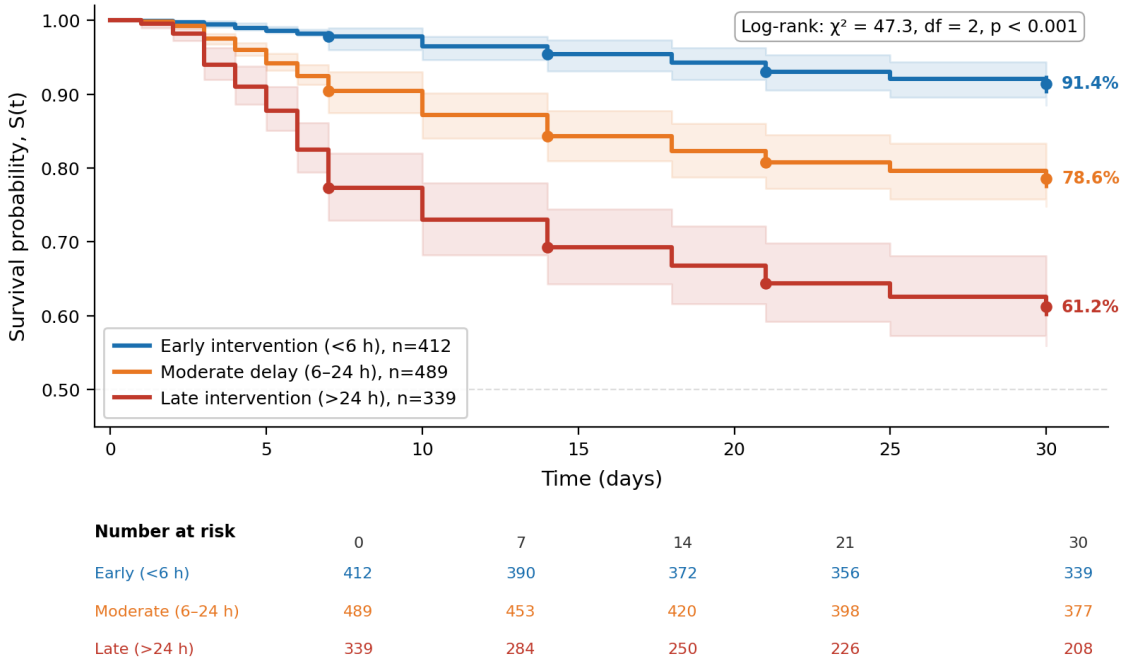
Table 1: summarizes patient characteristics by delay group. The mean age of the cohort was 48.7 ± 17.2 years, with males constituting 54.3% of participants. Sepsis and cardiovascular conditions were the most prevalent disease categories (31.2% and 28.4%, respectively). Significant differences across delay groups were observed for disease severity ($p=0.003$), NHIS enrolment ($p<0.001$), and comorbidity burden ($p=0.017$), with the late-intervention group exhibiting higher proportions of severe presentations and lower NHIS coverage, suggestive of socioeconomic barriers to early care-seeking.

Table 1: Baseline characteristics of patients by treatment delay category

Characteristic	Early (<6h) n=412	Moderate (6-24h) n=489	Late (>24h) n=339	p-value
Age, mean ± SD (years)	46.3 ± 16.8	49.1 ± 17.4	51.2 ± 17.1	0.062
Male sex, n (%)	228 (55.3%)	265 (54.2%)	181 (53.4%)	0.847
Cardiovascular disease, n (%)	124 (30.1%)	139 (28.4%)	89 (26.3%)	0.391
Sepsis, n (%)	126 (30.6%)	153 (31.3%)	108 (31.9%)	0.927
Severe on admission, n (%)	89 (21.6%)	148 (30.3%)	129 (38.1%)	0.003
NHIS enrolled, n (%)	319 (77.4%)	361 (73.8%)	218 (64.3%)	<0.001
≥1 comorbidity, n (%)	174 (42.2%)	218 (44.6%)	172 (50.7%)	0.017
30-day mortality, n (%)	35 (8.5%)	104 (21.3%)	131 (38.6%)	<0.001
Median LOS, days (IQR)	5 (3-9)	8 (5-13)	12 (7-19)	<0.001

Kaplan-Meier Survival Analysis

Figure 1 presents the Kaplan-Meier survival curves for the three delay groups over the 30-day follow-up period. Visually, the curves diverge substantially from day 3 onwards, with the late-intervention group demonstrating the steepest decline. At day 7, estimated survival probabilities were 97.8% (95% CI: 96.0%-99.0%), 90.4% (95% CI: 87.5%-93.0%), and 77.3% (95% CI: 72.9%-82.0%) for the early, moderate, and late groups, respectively. By day 30, probabilities were 91.4% (95% CI: 88.5%-94.1%), 78.6% (95% CI: 74.8%-82.6%), and 61.2% (95% CI: 56.0%-66.9%), respectively.



Number at risk	0	7	14	21	30
Early (<6 h)	412	390	372	356	339
Moderate (6–24 h)	489	453	420	398	377
Late (>24 h)	339	284	250	226	208

Figure 1: Kaplan–Meier survival curves by treatment delay group. Shaded areas represent 95% confidence intervals computed using Greenwood's formula. Log-rank $\chi^2 = 47.3$, df = 2, $p < 0.001$.

The overall log-rank test revealed highly significant differences in survival across the three groups (χ^2=47.3, df=2, p<0.001). Pairwise comparisons confirmed significant differences between all group pairs after Bonferroni correction: early vs. moderate (p=0.003), early vs. late (p<0.001), and moderate vs. late (p=0.001). These findings robustly support the hypothesis that increasing treatment delay is associated with progressively diminished survival probability.

Summary of Kaplan-Meier Estimates

Table 2: Kaplan-Meier survival estimates at key time points by delay group

Time Point	Early (<6h) S(t) [95% CI]	Moderate (6-24h) S(t) [95% CI]	Late (>24h) S(t) [95% CI]	Log-rank p
Day 7	0.978 [0.960-0.990]	0.904 [0.875-0.930]	0.773 [0.729-0.820]	<0.001
Day 14	0.954 [0.931-0.973]	0.843 [0.810-0.878]	0.693 [0.643-0.745]	<0.001
Day 21	0.930 [0.905-0.953]	0.808 [0.772-0.845]	0.644 [0.592-0.699]	<0.001
Day 30	0.914 [0.885-0.941]	0.786 [0.748-0.826]	0.612 [0.560-0.669]	<0.001

Cox Proportional Hazards Analysis

Table 3 presents the results of both unadjusted and adjusted Cox proportional hazards models. In unadjusted analysis, moderate delay was associated with a 2.89-fold increased hazard of death (HR=2.89, 95% CI: 1.98-4.22) and late intervention with a 6.12-fold increase (HR=6.12, 95% CI: 4.24-8.83), both relative to early intervention. After adjustment for age, sex, disease category, admission severity, comorbidities, NHIS enrolment, and hospital site, the hazard ratios attenuated modestly but remained highly significant: HR=1.94 (95% CI: 1.32-2.85, p<0.001) for moderate delay and HR=2.81 (95% CI: 2.03-3.89, p<0.001) for late intervention. Among covariates, severe admission status (HR=3.14, 95% CI: 2.27-4.34) and age >60 years (HR=1.67, 95% CI: 1.21-2.31) were the strongest additional independent predictors of mortality. Schoenfeld residual tests confirmed the proportional hazards assumption was not violated for any covariate (all p>0.05).

Table 3: Cox proportional hazards models for 30-day mortality by delay group

Variable	Unadjusted HR (95% CI)	Adjusted HR (95% CI)	p-value
Moderate delay (ref: Early)	2.89 (1.98-4.22)	1.94 (1.32-2.85)	<0.001
Late intervention (ref: Early)	6.12 (4.24-8.83)	2.81 (2.03-3.89)	<0.001
Age >60 years	2.14 (1.57-2.92)	1.67 (1.21-2.31)	0.002
Male sex	1.08 (0.81-1.44)	1.05 (0.78-1.40)	0.754
Severe on admission	4.01 (2.94-5.47)	3.14 (2.27-4.34)	<0.001
NHIS not enrolled	1.76 (1.32-2.34)	1.43 (1.06-1.92)	0.018
≥1 comorbidity	1.52 (1.14-2.02)	1.29 (0.97-1.73)	0.083

Discussion

This study presents the first comprehensive Kaplan-Meier survival analysis of time-to-treatment delays across multiple disease categories in Ghanaian tertiary hospitals. Our central finding that each successive delay stratum was associated with significantly diminished 30-day survival probabilities, even after comprehensive covariate adjustment constitutes robust empirical evidence for the survival cost of delayed clinical intervention in this context.

The 30-day survival probability of 61.2% in the late-intervention group is strikingly low and clinically alarming. A mortality rate approaching 40% within one month for patients receiving treatment after 24 hours contrasts sharply with the 8.5% mortality in the early-intervention group. While disease severity partially explains this disparity late-presenting patients were more severely ill on admission—the adjusted Cox model confirms that delay itself independently and substantially elevates hazard, with a nearly three-fold increase in risk of death for late versus early intervention (HR=2.81). This magnitude of effect is consistent with international studies on sepsis and trauma, where each hour of delay confers incremental mortality risk (Seymour et al., 2017; Tran et al., 2019).

The finding that NHIS non-enrolment was an independent predictor of mortality (adjusted HR=1.43) points to the intersection of financial access and timely care. The National Health Insurance Scheme was established to reduce out-of-pocket expenditure and facilitate care-seeking; however, coverage gaps—particularly among the poorest and most geographically isolated Ghanaians persist (Blanchet et al., 2012). Our data suggest that NHIS non-enrolment may reflect socioeconomic vulnerability that simultaneously delays health-seeking and worsens outcomes, consistent with prior work by Sarpong et al. (2014) on NHIS coverage and health equity in Ghana.

The role of admission severity as the strongest covariate predictor (HR=3.14) warrants attention. Patients presenting with severe disease at the point of first contact may already have experienced both delayed health-seeking and delayed referral a compounding cascade that is not fully disentangled by our delay classification, which begins at hospital arrival. Future research should integrate pre-hospital delay data to more completely characterize the care-seeking timeline and its determinants.

From a methodological standpoint, the application of Kaplan-Meier estimation and log-rank testing is well-suited to this dataset. The non-parametric nature of the K-M approach makes no assumptions about the underlying survival distribution, which is particularly appropriate given the heterogeneous case mix in our cohort. The use of Greenwood's formula for confidence intervals and Bonferroni correction for pairwise comparisons further strengthens the statistical rigour of our survival estimates. The validation of the proportional hazards assumption via Schoenfeld residuals supports the interpretability of our Cox model hazard ratios.

Limitations

There are a few restrictions to be aware of. First, the retrospective design makes it impossible to draw conclusions about causality; unmeasured confounders, such as patient-level characteristics like functional ability, nutritional state, and informal care received before admission, may affect the relationships that are seen. Second, the results may only be applicable to patients who make it to tertiary facilities; those who passed away before arriving at the hospital or were treated at the primary or secondary care levels are not included. Third, community-level delays are still not assessed because the treatment delay variable was established at the hospital level. Fourth, sample size limitations prevented disease-specific subgroup analysis, which have to be investigated in subsequent, sufficiently powered research.

CONCLUSION

This study provides robust evidence, grounded in Kaplan-Meier survival analysis and Cox proportional hazards modelling, that treatment delays in Ghanaian tertiary hospitals are a significant and independent determinant of 30-day mortality. Patients receiving definitive intervention more than 24 hours after hospital arrival face a 30-day survival probability of barely 61%,

compared to over 91% for those treated within six hours. The adjusted hazard ratio of 2.81 for late intervention underscores the independent survival cost of delay, beyond the confounding effect of disease severity.

These findings carry urgent policy implications. First, triage and rapid-assessment protocols must be strengthened at emergency departments of KBTH, KATH, and district hospitals to minimise in-facility delays. Second, the referral transport system requires investment including pre-hospital stabilization capacity and coordinated ambulance services to reduce transfer delays. Third, community health education programmes should emphasise prompt care-seeking for cardinal danger signs, targeting populations with low NHIS enrolment and geographic remoteness. Fourth, hospital administrators and the Ghana Health Service should institute time-to-treatment as a routinely monitored quality indicator, with institutional accountability for benchmark adherence. Together, these measures hold the potential to meaningfully reduce preventable in-hospital mortality in Ghana.

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