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Factors associated with hospital length of stay in patients admitted with suspected malaria in Kenya: secondary analysis of a cross-sectional survey

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ABSTRACT

Objectives To investigate factors associated with hospital length of stay (LOS) in patients admitted with suspected malaria using a competing risk approach.

Setting County government referrals and major faith-based hospitals in Kenya in 2018.

Design Secondary analysis of a cross-sectional survey data.

Participants Data were extracted from 2396 medical records of patients admitted with suspected malaria at 90 hospitals.

Outcome measures LOS, defined as time to discharge, was the primary event of interest, and time to death was the competing event against patient factors assessed during admission and hospitalisation.

Results Among the patients analysed, 2283 were discharged, 49 died and 64 were censored. The median LOS was 4 days (IQR: 3–6 days). The cumulative incidence of discharge significantly decreased (p<0.05) by 12.7% (subdistribution-HR (SDHR): 0.873; 95% CI 0.789 to 0.967) when the respiratory rate was assessed, by 14.1% (SDHR 0.859; 95% CI 0.754 to 0.978) when oxygen saturation was monitored, by 23.1% (SDHR 0.769; 95% CI 0.709 to 0.833) and 23.4% (SDHR 0.766; 95% CI 0.704 to 0.833) when haemoglobin/haematocrit and glucose/random blood sugar were performed, respectively, and by 30.4% (SDHR 0.696; 95% CI 0.626 to 0.774) when patients had at least one clinical feature of severe malaria. Conversely, patients with confirmed severe malaria and those treated with injectable artesunate had a significantly increased cumulative incidence of discharge by 21.4% (SDHR 1.214; 95% CI 1.082 to 1.362) and 33.9% (SDHR 1.339; 95% CI 1.184 to 1.515), respectively.

Conclusions Factors of inpatient clinical processes that influence hospital LOS were identified. These can be targeted during quality improvement interventions to enhance health service delivery in Kenya. Early recognition and appropriate management of the signs of malaria severity could greatly affect beneficial outcomes. Strengthening clinical practices and nursing care according to national case management guidelines should be a priority for malaria control managers in Kenya.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This study analysed a large dataset of hospital admissions under routine, real-world conditions of inpatient service delivery.
⇒ The results are nationally representative for major hospitals and may not be inferred to the smaller health facilities.
⇒ The study did not account for malaria comorbidity that might influence the length of stay.
⇒ The basic clinical parameters modelled are rarely subject to documentation bias.

INTRODUCTION

Malaria is a leading cause of morbidity and mortality, disproportionately affecting children under 5 years of age and pregnant women in many developing countries. In 2019, approximately 229 million cases and 409 000 malaria deaths were recorded worldwide. The WHO African Region accounted for 94% of the cases.[1] In Kenya, malaria is a major public health and socioeconomic problem, with three-quarters of the population at risk across various epidemiological zones.[2] In 2020, the prevalence of malaria in children was 5.6%, with the highest prevalence (18.9%) in the Lake Endemic zone in the western part of the country and the lowest (<1%) in the Low-risk zone around the central highlands.[3]

Severe malaria is associated with high mortality if untreated within 24 hours.[4] Comprehensive assessment of patients with suspected malaria is recommended on admission and during hospitalisation to optimise care and prevent further complications.[4 5] Patient triaging during routine admissions and monitoring of vital clinical and laboratory measurements in the wards such as temperature, blood pressure, pulse rate, respiratory rate, and assessment of the

level of consciousness, oxygen saturation, blood glucose, haemoglobin (Hb) level and urine output[6–12] are the basic management standards. Moreover, effective malaria case management comprises appropriate antimalarial and supportive therapy. Finally, patients with suspected severe malaria are recommended to have a parasitological diagnosis irrespective of fever and should be managed in a facility with inpatient services with expertise and infrastructure for adequate management.[4]

The patient outcomes of being discharged home after treatment for malaria and the associated hospital length of stay (LOS) are not only dependent on the patient's clinical factors, but also on the quality of case management provided on admission and during hospitalisation.[13 14] However, the discharge outcome can be interrupted by death as a competing risk.[15] Competing risk analysis accurately evaluates LOS by estimating the marginal probability of an event in the presence of competing events using the cumulative incidence function (CIF). CIF avoids overestimation and bias resulting from applying general survival models that ignore competing risks.[16 17]

Predicting LOS for patients is an important measure in hospital service planning, resource allocation, and monitoring of the quality of healthcare.[18] Assessing and modifying factors that influence hospital LOS for suspected malaria patients in the presence of competing risk events can lead to the optimisation of service delivery in resource-limited settings.[13] The effect of the factors is determined using the cause-specific or subdistribution hazard (SDH) function.[17] The cause-specific hazard (CSH) is estimated by removing individuals from the risk set when they experience the competing event by treating them as censored observations. In addition, CSH can be estimated by fitting a standard Cox proportional hazards model that determines the effect of factors on the survival function by assuming that hazard functions are proportional over time.[19] The CSH model is considered more appropriate for aetiological research, as it directly quantifies subjects who are at risk of developing an event of interest.[17] The SDH model is also retained within the risk set for subjects who are free of the event and those who experience the competing event. It relies on the precise accounting of the number of subjects who fail because of the event of interest, those who fail because of competing events, and those who are censored.[20] The SDH model is most appropriate for prediction research, given the direct relationship between these factors and CIF.[21]

Identifying the factors that predict the time to discharge is the core of quality of care analysis. However, previous studies on the quality of care for inpatient malaria have assessed levels and trends in system readiness to implement the recommended malaria case management policies following a large clinical trial and change in therapeutic policies.[22–24] Studies investigating the factors influencing hospital LOS for malaria are scarce. Only one study was conducted in malaria-endemic areas, notably under controlled clinical trial conditions in areas with low malaria risk in Southeast Asia.[13] Another observational study investigated malaria LOS predictors in a high-resource tertiary hospital in Germany.[14] Studies based in routine clinical settings from low resource but high malaria risk areas in Africa have not been undertaken. In this study, the factors associated with hospital LOS for patients admitted with suspected malaria in the presence of competing risk events were examined in routine clinical settings in Kenya.

METHODS

Description of the data

This study was based on a secondary analysis of data from a cross-sectional survey conducted in 2018 to monitor the progress in the readiness of systems and the quality of inpatient malaria management in hospitals in Kenya. Purposive sampling was applied to select all county government referral (GOK) and major faith-based organisation (FBO) hospitals in all 47 counties. The study sites included 90 hospitals (47 GOK and 43 FBO hospitals), consisting of 2396 medical files of patients admitted with suspected malaria up to 6 months prior to the survey. At each of the surveyed hospitals, data were collected retrospectively by reviewing patients' admission files from the hospital medical record office. Prior to data extraction from individual patient files, inpatient and laboratory registers were screened to select 30 consecutive patients (15 from paediatric and 15 from medical wards) at GOK hospitals and 34 consecutive patients (17 from paediatric and 17 from medical wards) at FBO hospitals. The number of targeted medical files at the FBO hospitals was greater to adjust the sample size for a lower number of surveyed hospitals within the FBO sector. From each ward, patients discharged in chronological order, counting backward prior to the survey day, were included. Thereafter, from each of the selected patient files, data were extracted from all available forms, including structured and unstructured admission, continuation, observation, treatment, nursing care, discharge and laboratory forms, depending on the type of records used at the hospital.

Inclusion criteria reflecting suspected malaria admission comprised any form of malaria diagnosis made, malaria test performed or antimalarial treatment prescribed. The presence of clinical criteria for severe malaria was established on admission as documented either at the time of casualty or within 24 hours on admission to the ward. All patients with a malaria test ordered either on admission or post-admission and with no results recorded were traced back to the laboratory register to establish whether the test was performed and to determine the test result. More information on the methodology used in this study can be found elsewhere.[25]

Patient and public involvement statement

No patients were involved in developing the hypotheses, research questions or outcome measures, and no patients were involved in planning for the design

or implementation of the study. There were no plans to disseminate the results of this research to the study participants.

National standard case definitions for uncomplicated and severe malaria

The malaria treatment guidelines[4] in Kenya specify that a patient who presents with symptoms of malaria and a positive parasitological test, microscopy or rapid diagnostic test but with no features of severe malaria is defined as having uncomplicated malaria. Severe malaria is defined by the detection of malaria parasitaemia in the presence of any of the following clinical and laboratory criteria: prostration (inability to drink, breastfeed, sit, stand, walk); alteration of consciousness level (from drowsiness to coma); respiratory distress (acidotic breathing); convulsions (two or more); shock; pulmonary oedema; abnormal bleeding; jaundice; haemoglobinuria; acute renal failure (oliguria/anuria); severe anaemia (Hb <50 g/L or haematocrit (HCT) <15%), hypoglycaemia (blood glucose <2.2 mmol/L) and hyperlactataemia.

Outcomes, factors examined and definitions

LOS, defined as the time to discharge from the hospital (in days) for patients admitted with suspected malaria, was regarded as the primary outcome or event of interest. The time to death during hospitalisation was considered a competing event and was used to explain its effect on modelling the time to discharge. Transferred, referred and absent patients were censored. The association with LOS outcome was examined for the following factors: patient age (<5 vs >5 years), sex (male vs female), and ward allocation (paediatric vs medical ward); documentation of the performance of basic assessment tasks on admission (weight, temperature, respiratory rate, blood pressure and fever assessment), documentation of the performance of vital signs monitoring during hospitalisation (temperature, respiratory rate, blood pressure, pulse rate and oxygen saturation); performance of laboratory tests on admission and during hospitalisation (malaria, Hb/HCT, glucose/random blood sugar, RBS); documentation of at least one severe malaria feature (see clinical features in table 1); health workers' diagnosis of severe malaria made on admission; and treatment by injectable artesunate online supplemental table 1. Finally, association was examined for confirmed severe malaria diagnosis based on a positive malaria test and severity criteria comprising documentation of at least one severe malaria feature or diagnosis of severe malaria made on admission by a health worker. Clinical severity features were complemented with health workers' diagnoses of severe malaria to mitigate potential documentation biases of routinely recorded clinical features.

Statistical analysis

Exploratory data analysis and descriptive analysis were performed to summarise all variables used in the study. Non-normally distributed variables are summarised as medians and IQRs. χ^2 tests of significance were used to determine the associations between categorical variables. Consequently, the competing risk in the survival analysis modelling approach was applied to study hospital LOS and its related factors.

The occurrence of a competing event tends to lower the cumulative survival probability, because the number of persons at risk decreases over time. In the presence of competing risks, hazard and cumulative incidence cannot be estimated from a single model; thus, different models need to be applied to answer aetiological and prognostic epidemiological research questions.[17 26] In this study, both subdistribution model and cause-specific model were used to evaluate the effects of factors on the cumulative probability of being discharged, considering that a patient can die during the hospitalisation period. Online supplemental file 1 provides a more detailed description of competing risk modelling.

Competing risk was analysed using the CIF, which indicates the probability of experiencing the event of interest before a specific time and before the occurrence of any other type of event. CSH ratio (CSHR) analysis was used to explore factors related to the duration of hospitalisation for patients admitted with suspected malaria. The subdistribution HR (SDHR) was used to examine the association of LOS with cumulative incidence, accounting for competing risks. Factors from univariable CSHR and SDHR analyses were performed against the time to event (discharge), and those found to be significant ($p<0.05$) were assessed in a multivariable model for the time to event adjusted for other factors at the various stages of hospitalisation. CI were reported at 95%. Statistical significance was set at $p<0.05$. Findings were reported according to the REporting of studies Conducted using Observational Routinely collected Data Statement online supplemental table 2. Analysis was performed using StataCorp V.14 (Stata Statistical Software: Release 14, StataCorp).

RESULTS

Description of study population

A total of 2396 medical files of patients admitted with suspected malaria from 90 hospitals were reviewed (table 1). Of the 2396 reviewed files, 588 (24.5%) met the inclusion criteria based on malaria admission diagnosis, and 2214 (92.4%) based on malaria testing. With respect to admission wards, 1207 (50.4%) patients were admitted to the paediatric ward and 1189 (49.6%) were admitted to adult medical wards. Male patients accounted for 52.4% of the admissions. The median age of the paediatric and medical ward patients was 3 years (IQR: 1–6) and 32 years (IQR: 22–37), respectively. The median duration of illness prior to admission and the length of admission was 3 and 4 days, respectively.

On admission, health workers variably performed basic assessment tasks, such as age (99.6%), weight (48.9%), pulse (69.6%), temperature (81.6%), respiratory rate (53.3%), blood pressure (45.0%) and history of fever

Table 1 Description of study population, by admission ward

	Paediatric ward (N=1207)	Medical ward (N=1189)	All patients (2396)
	n (%)	n (%)	n (%)
General information			
Sex (male)	689 (57.4)	561 (47.3)	1250 (52.4)
Age in years (median, IQR)	3 (1–6)	32 (22–47)	13 (3–32)
Illness duration in days (median, IQR)	3 (2–4)	3 (2–5)	3 (2–5)
Basic assessment performance on admission			
Age	1201 (99.5)	1186 (99.8)	2387 (99.6)
Weight	922 (76.4)	250 (21.0)	1172 (48.9)
Pulse	716 (59.3)	952 (80.1)	1668 (69.6)
Temperature	1106 (91.6)	849 (71.4)	1955 (81.6)
Respiratory rate	682 (56.5)	593 (50.0)	1275 (53.3)
Blood pressure	74 (6.2)	1004 (84.4)	1078 (45.0)
History of fever	1145 (94.5)	941 (79.1)	2086 (87.1)
Vital signs monitored during hospitalisation			
Temperature	1129 (93.5)	879 (73.9)	2008 (83.8)
Respiratory rate	741 (61.4)	652 (54.8)	1393 (58.1)
Blood pressure	89 (7.4)	1032 (86.8)	1121 (46.8)
Pulse rate	765 (63.4)	982 (82.6)	1747 (72.9)
Oxygen saturation	338 (28.0)	147 (12.4)	485 (20.2)
Documented presence of severe malaria features			
Altered consciousness*	125 (10.4)	208 (17.5)	333 (13.9)
Convulsions (two or more)†	152 (12.6)	32 (2.7)	184 (7.7)
Prostration‡	112 (9.3)	58 (4.9)	170 (7.1)
Severe anaemia§	70 (5.8)	33 (2.8)	103 (4.3)
Respiratory distress¶	64 (5.3)	26 (2.2)	90 (3.8)
Jaundice**	38 (3.2)	58 (4.9)	96 (4.0)
Shock††	25 (2.1)	24 (2.0)	49 (2.1)
Abnormal bleeding‡‡	6 (0.5)	12 (1.0)	18 (0.8)
Renal failure§§	9 (0.8)	8 (0.7)	17 (0.7)
Haemoglobinuria¶¶	5 (0.4)	10 (0.8)	15 (0.6)
Hypoglycaemia***	6 (0.5)	4 (0.3)	10 (0.4)
Pulmonary oedema†††	1 (0.1)	5 (0.4)	6 (0.3)
At least one of the above features of severe malaria	442 (36.6)	357 (30.0)	799 (33.4)
Laboratory testing practices			
Malaria test done on admission	1112 (92.1)	1102 (92.7)	2214 (92.4)
Malaria test positive	587 (52.8)	560 (50.8)	1147 (51.8)
Malaria test done post admission	77 (6.4)	67 (5.6)	144 (6.0)
Haemoglobin (Hb) or heamatocrit (HCT) done	830 (68.8)	767 (64.5)	1597 (66.7)
Glucose/random blood sugar done	245 (20.3)	359 (30.2)	604 (25.2)
Malaria diagnosis			
Clinicians' diagnosis of severe malaria	322 (26.7)	266 (22.4)	588 (24.5)
Confirmed severe malaria‡‡‡	347 (28.8)	262 (22.0)	609 (25.4)
Treatment during hospitalisation			
Artesunate injection prescribed	647 (53.6)	570 (47.9)	1217 (50.8)

Continued

Table 1 Continued

	Paediatric ward (N=1207)	Medical ward (N=1189)	All patients (2396)
	n (%)	n (%)	n (%)
Malaria outcome			
Discharged	1167 (96.7)	1116 (93.9)	2283 (95.3)
Died	12 (1.0)	37 (3.1)	49 (2.1)
Absconded	1 (0.1)	4 (0.3)	5 (0.2)
Referred	26 (2.2)	30 (2.5)	56 (2.3)
Discharged against medical advice	1 (0.1)	2 (0.2)	3 (0.1)

*Documented 'drowsiness, lethargy, confusion, unconsciousness, coma or Glasgow Coma Scale(GCS)<15'/Alert/Verbal/Painful/Unresponsive(AVPU) <A'.
†Documented 'convulsions, fits or seizures'.
‡Documented 'unable to drink/breastfeed/sit/stand/walk or prostrated'.
§Documented Hb <5 g/L or HCT <15%'
¶Documented 'acidotic/deep breathing, chest in-drawing, or respiratory distress'.
**Documented 'jaundice'
††Documented 'capillary refill ≥3 s, systolic BP <80 mm Hg in adults/<70 mm Hg in children or shock'.
‡‡Documented 'bleeding'.
§§Documented 'oliguria, anuria, reduced urine output or renal failure'.
¶¶Documented 'dark urine, blood in urine, haematuria'.
***Documented 'blood sugar <2.2 mmol'.
††† Documented 'pulmonary oedema'.
‡‡‡Positive malaria test and severity criteria defined as documentation of at least one severe malaria feature or diagnosis of severe malaria made on admission by a health worker.
BP, blood pressure.

(87.1%). During hospitalisation, vital signs were monitored at the highest for temperature (83.8%) and lowest for oxygen saturation (20.2%). One-third of the patients (33.4%) had at least one clinical feature of severe malaria documented in the reviewed files, with a slightly higher prevalence in the paediatric ward than in the medical ward (36.6% vs 30.0%; p=0.001). Most patients (92.4%) were tested for malaria on admission, including children (92.1%) and patients in the medical wards (92.7%). Approximately two-thirds (66.7%) of the patients had their Hb or HCT determined (68.8% children vs 64.5% adults; p=0.063), while 25.2% had glucose/RBS levels measured (20.3% children vs 30.2% adults; p<0.001).

A quarter (24.5%) of the patients were diagnosed by health workers as having severe malaria on admission, while a similar proportion (25.4%) of the patients were classified as having confirmed severe malaria based on the study criteria. With respect to antimalarial treatment, approximately half (50.8%) of the patients were prescribed injectable artesunate, including 53.6% of the children and 47.9% of the adults in the medical ward (p=0.048). Of the 2396 admitted patients, 2283 (95.3%) were discharged and 49 (2.1%) died. The remaining 64 (2.6%) patients were either referred, absent or discharged against medical advice (table 1).

Factors associated with hospital LOS

The median LOS or time to discharge for admitted patients was 4 days (IQR 3–6 days; range 1–46 days). Time to discharge had a right-skewed distribution, with most patients discharged on the third day (27.5%), and cumulatively 82.6% were discharged by the sixth day of admission (figure 1). After excluding 64 censored patients who were either referred, absconded or discharged against medical advice, the final model included 2332 patients, of whom 2283 were discharged alive and 49 died, and therefore, presented competing risks. Online supplemental table 1 shows the univariate analysis results that identified potential factors associated with hospital LOS using the CSHR and SDHR. Significant factors (p<0.05) from univariate analyses were assessed using a multivariable model. Patient age, weight, sex and ward allocation were not significantly associated with the examined outcomes in the univariable analysis.

The multivariable model (table 2) revealed a significant (p<0.05) decrease in the discharge rate when temperature was measured on admission and during hospitalisation (by 10.9% and 13.3%, respectively), when the respiratory rate was assessed on admission (by 14.4%), when oxygen saturation was monitored during hospitalisation (by 13.1%), when Hb/HCT and glucose/RBS levels were measured (by 26.8% and 19.2%, respectively), and by 25.3% if patients had documentation of at least one clinical feature of severe malaria. Conversely, the adjusted discharge rate increased by 21.9% when patients presented with confirmed severe malaria and by 36.5% when patients were treated with injectable artesunate. With respect to the cumulative incidence of discharge, the multivariable model showed that assessment of

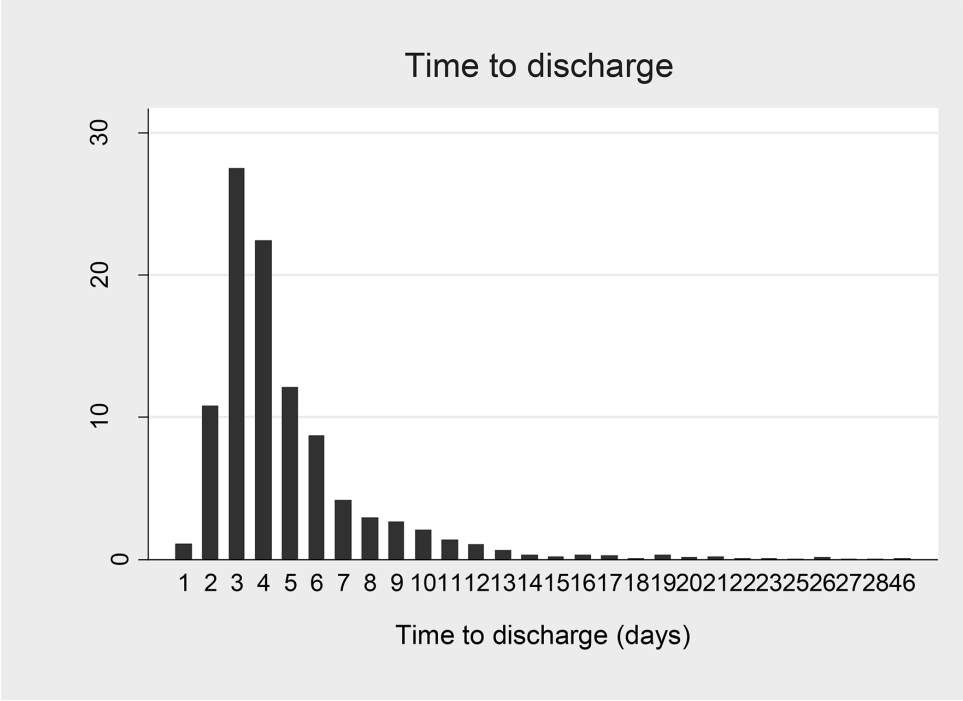

Figure 1 Distribution of time to discharge for patients admitted with suspected malaria.

respiratory rate decreased incidence by 12.7%, monitoring of oxygen saturation decreased it by 14.1%, and performance of Hb/HCT and glucose/RBS blood tests by 23.1% and 23.4%, respectively; if patients had documentation of at least one clinical feature of severe malaria, the cumulative incidence of discharge decreased by 30.4%. In contrast, patients with confirmed severe malaria and those treated with injectable artesunate had an increased cumulative incidence of discharge by 21.4% and 33.9%, respectively.

DISCUSSION

The study findings revealed that the median hospital LOS, or time to discharge, for patients admitted with suspected malaria under routine conditions of hospitalisation was 4 days in Kenya. We found LOS significantly shorter than the 7 days reported under trial conditions in South East Asia[13] and slightly longer than the 3 days LOS reported in a retrospective observational study from a tertiary hospital setting in Germany.[14] The reported LOS differences between studies likely reflect the severity specifics of the studied malaria populations ranging from exclusively focused severe malaria patients in Southeast Asia[13] over a quarter of severe malaria cases estimated in our study to only 10% of severe cases included in the malaria sample in Germany.[14]

Competing risk analysis revealed several factors influencing LOS for suspected malaria patients that can inform routine service delivery in hospital settings in Kenya and contribute to the body of knowledge on malaria LOS internationally. First, we found the strongest association between sicker patients (those with at least one sign of malaria severity) and prolonged LOS, findings similar to those reported in previous malaria studies.[13 14] We have not examined the association with individual features of malaria severity because non-documentation of clinical signs and symptoms is a common characteristic of routine information systems in Africa.[27 28] However, we used a cumulative measure of malaria severity since most patient files have at least one documented sign of severity, and only one sign is necessary to classify a case as severe.[29] Considering the study findings and commonly reported suboptimal inpatient care across the continent,[25 30–34] strengthening of clinical practices for early recognition of severity signs and appropriate management of well-established sets of severe malaria complications according to national and international guidelines[4 5] is a priority for healthcare implementers.

Second, structured vital sign charts allowed us to examine the association between LOS and the performance of these tasks as quality-of-care markers. We found that the measurement of several vital signs (temperature, respiratory rate and oxygen saturation) was significantly associated with shortened LOS. The low performance of vital sign monitoring, especially respiration counts and oxygen saturation in this study, as well as generally suboptimal performance of nursing care in this domain in Kenya,[35] is an area requiring targeted interventions not only for malaria but systematically for all admitted patients. Third, we also found that shortened LOS was significantly associated with the performance of laboratory tests, such as Hb/HCT and glucose/RBS measurements. In contrast to malaria testing, which after nationwide 'test and treat' campaigns and associated health worker trainings

Table 2 Multivariable analysis of factors associated with hospital length of stay using a conventional Cox regression model to obtain a cause-specific HR and using the Fine and Gray competing-risks method to obtain a subdistribution HR, adjusting for health facility structures

	Whole Sample N=2332	Cause-specific hazard (rate of discharge)		Subdistribution-hazard (association with cumulative incidence of discharge)	
Factors	**n (%)**	**Adjusted CSHR (95% CI)**	**P value**	**Adjusted SDHR (95% CI)**	**P value**
Assessment on admission					
Pulse	1618 (69.4)	0.933 (0.848 to 1.026)	0.152	0.932 (0.843 to 1.031)	0.173
Temperature	1900 (81.5)	0.891 (0.798 to 0.994)	**0.039**		
Respiratory rate	1232 (52,9)	0.856 (0.763 to 0.959)	**0.008**	0.873 (0.789 to 0.967)	**0.009**
Monitoring during hospitalisation					
Temperature	1953 (83.7)	0.867 (0.764 to 0.984)	**0.028**		
Respiratory rate	1349 (57.8)	0.896 (0.793 to 1.013)	0.078	0.895 (0.795 to 1.007)	0.064
Pulse rate	1696 (72.7)	0.956 (0.862 to 1.060)	0.390		
Oxygen saturation	469 (20.1)	0.869 (0.758 to 0.998)	**0.046**	0.859 (0.754 to 0.978)	**0.022**
Laboratory testing					
Hb/HCT done	1551 (66.5)	0.732 (0.675 to 0.794)	**<0.001**	0.769 (0.709 to 0.833)	**<0.001**
Glucose/RBS test done	582 (25.0)	0.808 (0.733 to 0.891)	**<0.001**	0.766 (0.704 to 0.833)	**<0.001**
Clinical features					
At least one feature of severe malaria*	762 (32.7)	0.747 (0.679 to 0.821)	**<0.001**	0.696 (0.626 to 0.774)	**<0.001**
Diagnosis					
Confirmed severe malaria†	592 (25.4)	1.219 (1.090 to 1.362)	**0.001**	1.214 (1.082 to 1.362)	**0.001**
Treatment					
Artesunate injection treatment	1186 (50.9)	1.365 (1.206 to 1.545)	**<0.001**	1.339 (1.184 to 1.515)	**<0.001**

Significant results (p<0.05) are indicated by values in bold.
*Documentation of at least one of the clinical and laboratory features as specified and defined in table 1.
†Defined as positive malaria test on admission and presence of severity criteria (either documentation of any clinical features of severe malaria or severe malaria diagnosis made by clinicians); clinical severity criteria were complemented with health workers' diagnosis of severe malaria to protect the correctness of severity classification from documentation biases.
CSHR, cause-specific HR; Hb, haemoglobin; HCT, haematocrit; RBS, random blood sugar; SDHR, subdistribution-HR.

became well established and nearly universal practice for malaria suspected admissions in Kenya,[23] the systematic performance of other laboratory tests supporting early detection of common malaria complications such as severe anaemia and hypoglycaemia require major quality improvement interventions. The widespread availability of laboratory services for anaemia and blood sugar testing within Kenyan hospitals is more behavioural than the availability of testing shortcomings.

Fourth, confirmed severe malaria and injectable artesunate treatment were significantly associated with prolonged LOS. While this pattern is intuitively expected for confirmed severe malaria and, together with previously shown association with severity features, simply shows that sicker patients require longer recovery, the association with artesunate treatment practice is less clear, though not previously unobserved.[13] Since artesunate is the most effective treatment for severe malaria,[24] a possible explanation for prolonged LOS could be that artesunate use is simply a marker for sicker patients in our data set or, as previously suggested, that its use may prolong the death in patients who would have otherwise died earlier.[13] Nevertheless, optimisation of early recognition of severity signs, prompt malaria testing, and parenteral use of artesunate for test-positive severe, but not uncomplicated and test-negative cases, remain the cornerstone of malaria testing and treatment management.[4 5]

Finally, considering the statistical aspect, the effect of the factors on the hazard of discharge, given a competing event (death), was determined by observing the estimates obtained from the CSH and SDH models.[17 19 20] The results showed that the factor estimates and the CI spans between the SDH and CSH models were slightly varied. Based on these results, the competing event (death) affected the estimation of the factors of the event of interest (discharge).[13 17 36] The results support the argument that ignoring competing risks and applying standard survival models to data that includes competing events leads to

biased estimates consequently biased conclusion. In the presence of competing risk, the SDH model is better than the CSH model in identifying prognostic factors.[16 27]

Strengths and limitations

The study provides a national representation of hospitals and analyses a large dataset of admissions under routine, real-world conditions of inpatient service delivery. However, the findings are limited to county referral and major faith-based hospitals and cannot be inferred for smaller health facilities where inpatient malaria care is also provided. The study did not account for severe malarial comorbidities that might influence LOS. Data extraction from routine hospital records is commonly subject to documentation biases, which prompted us to limit modelling to the set of basic clinical predictors that are routinely recorded in admission files such as age, sex, vital signs, testing, diagnosis and treatment.

Conclusion

Our study findings revealed that the LOS for patients admitted with suspected malaria under routine hospitalisation conditions was 4 days in Kenya. Using a competing risk approach, we identified seven factors of inpatient clinical processes that influence hospital LOS and can be specifically targeted during quality improvement interventions to enhance health service delivery in Kenya. Early recognition and appropriate management of the signs of malaria severity may have the greatest effect on beneficial outcomes. Strengthening clinical practices and nursing care according to national case management guidelines should be a priority for malaria control managers in Kenya.

Collaborators Not applicable.

BM BM, TNOA and HK designed the study. JC and BA contributed to the analysis and interpretation of the study findings. BM wrote the first draft of the manuscript and is the guarantor. All authors reviewed and approved the final version of the manuscript.

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Data availability statement Data are available on reasonable request. The data used are available on request by submitting a letter indicating the proposed use and justification to the Head of the Kenya DNMP.

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Supplementary Files

Supplementary Table 1: Univariable analysis of factors associated with hospital length of stay, using a conventional Cox regression model to obtain a cause-specific hazard ratio, and the Fine and Gray competing-risks method to obtain a subdistribution hazard ratio, adjusting for health facility structures.

	Whole Sample N=2,332	**Cause-specific Hazard (Rate of Discharge)**		**Subdistribution-Hazard (Association With Cumulative Incidence of discharge)**	
Factors	**n(%)**	**CSHR(CI)**	***P* value**	**SDHR(CI)**	***P* value**
General information					
Age category (more 5 years)	1,525(65.7)	1.048(0.968; 1.135)	0.244	1.018(0.948; 1.094)	0.625
Age taken	2,323(99.6)	0.772(0.512; 1.163)	0.213	0.756(0.507; 1.126)	0.168
Sex (male)	1,211(52.1)	0.980(0.914; 1.051)	0.564	0.952(0.886; 1.022)	0.177
Ward (paediatric)	1,179(50.6)	0.992(0.918; 1.073)	0.843	1.039(0.967; 1.116)	0.302
Assessment on admission					
Weight	1,146(49.1)	1.023(0.925; 1.131)	0.657	1.063(0.967; 1.169)	0.206
Pulse	1,618(69.4)	0.845(0.752; 0.950)	**0.005**	0.869(0.777; 0.972)	**0.014**
Temperature	1,900(81.5)	0.816(0.722; 0.921)	**0.001**	0.905(0.796; 1.030)	0.130
Respiratory rate	1,232(52,9)	0.806(0.713; 0.911)	**0.001**	0.848(0.759; 0.946)	**0.003**
Blood pressure	1,046(44.9)	0.951(0.875; 1.034)	0.234	0.936(0.865; 1.013)	0.102
Fever complaint	2,030(87.1)	0.955(0.817; 1.117)	0.562	0.995(0.858; 1.154)	0.948
Monitoring during hospitalization					
Temperature	1,953(83.7)	0.791(0.687; 0.910)	**0.001**	0.862(0.742; 1.002)	0.053
Respiratory rate	1,349(57.8)	0.828(0.727; 0.943)	**0.005**	0.874(0.775; 0.985)	**0.027**
Blood pressure	1,089(46.7)	0.958(0.885; 1.037)	0.280	0.935(0.867; 1.007)	0.078
Pulse rate	1,696(72.7)	0.860(0.759; 0.973)	**0.017**	0.886(0.782; 1.004)	0.058
Oxygen	469(20.1)	0.820(0.718; 0.938)	**0.004**	0.837(0.733; 0.955)	**0.008**

saturation					
Laboratory testing					
Malaria test done on admission	2,155(92.4)	1.046(0.880; 1.243)	0.607	1.120(0.926; 1.354)	0.242
Hb/ HCT done	1,551(66.5)	0.708(0.650; 0.771)	**<0.001**	0.738(0.678; 0.803)	**<0.001**
Glucose/RBS test done	582(25.0)	0.769(0.695; 0.850)	**<0.001**	0.733(0.673; 0.799)	**<0.001**
Clinical features					
At least one feature of severe malaria[a]	762(32.7)	0.747(0.679;0.821)	**<0.001**	0.696(0.626;0.774)	**<0.001**
Diagnosis					
HW's severe malaria diagnosis on admission	571(24.5)	1.063(0.953;1.186)	0.267	1.054(0.937;1.185)	0.380
Confirmed severe malaria [b]	592(25.4)	1.219(1.090;1.362)	**0.001**	1.214(1.082;1.362)	**0.001**
Treatment during the hospitalization					
Artesunate injection prescribed	1,186(50.9)	1.365(1.206; 1.545)	**<0.001**	1.339(1.184; 1.514)	**<0.001**

The bold values are those that are significant results (P <0.05)

[a] Documentation of at least one of the clinical and laboratory features as specified and defined in Table 1.

[b] Defined as positive malaria test on admission and presence of severity criteria (either documentation of any clinical features of severe malaria or severe malaria diagnosis made by clinician); Clinical severity criteria were complemented with health workers diagnosis of severe malaria to protect correctness of severity classification from documentation biases.

Supplementary Files

Supplementary Information (SI): Competing risk modelling

The hazard function, which is a function of time, describes the instantaneous rate of occurrence of the event of interest in subjects who are still at risk of the event.[1] In the absence of competing risks, the hazard function is defined as:

$$\lambda(\mathrm{t}) = \lim_{\Delta t \to 0} \frac{Prob(t \leq T < t + \Delta t | T \geq t)}{\Delta t}$$

where T is the time from baseline time until the occurrence of the event of interest.

In the presence of competing risks, the cause-specific hazard function and the subdistribution hazard function are of importance.

The CSHR denotes the instantaneous rate of occurrence of the k^{th} event in subjects who are currently event free (the subject is removed from the risk set the moment they experience the competing event or are censored). The CSHR function [2] is defined as:

$$\lambda_k^{cs}(t) = \lim_{\Delta t \to 0} \frac{Prob(t \leq T < t + \Delta t, D = k | T \geq t)}{\Delta t}$$

where D is a variable denoting the type of event that occurred and the function

The SDHR denotes the instantaneous risk of failure from the k^{th} event in subjects who have not yet experienced an event of type k. The subjects who experience the competing event still remain in the risk set. In this study it means the risk set has both the discharged patients and those who have died from suspected severe malaria. Fine and Gray recommended modeling the effects of covariates on a subdistribution hazard function [2] defined as:

$$\lambda_k^{sd}(t) = \lim_{\Delta t \to 0} \frac{Prob(t < T \leq t + \Delta t, D = k | T > t \cup (T < t \cap K \neq k))}{\Delta t}$$

Both models account for competing risks by modeling the effect of covariates on different hazard functions. There is a distinct cause-specific hazard function for each of the distinct types of events and a distinct subdistribution hazard function for each of the distinct types of events.[3] The SDHR model is considered the right model for prediction research as it allows one to estimate the effect of covariates on the cumulative incidence function for the event of interest[4] defined as:

$$CIF_k\ (t) = 1 - exp\{\ \hat{\mathrm{H}}_k(t)\}$$

where $\hat{\mathrm{H}}_k(t) = \int_0^t \hat{\mathrm{h}}_k(t)dt$ is a cumulative subhazard as $\hat{\mathrm{h}}_k(t) = \lambda_k^{sd}(t)$

The CIF allows for estimation of the incidence of the occurrence of an event while taking competing risk into account. In the competing risks setting, only one event type can occur, such that the occurrence of one event precludes the subsequent occurrence of other event types. The cumulative incidence function for the k^{th} cause is defined as:

$$CIF_k\ (t) = \Pr(T \leq t, D = K)$$

where D is a variable denoting the type of event that occurred and the function $CIF_k\ (t)$ denotes the probability of experiencing the k^{th} event before time t and before the occurrence of a different type of event.

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