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Mortality pattern and factors associated with prolonged hospital stay among admitted dengue fever patients during the ongoing war in Sudan: A hospital-based cross-sectional study

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ABSTRACT

Objective: To assess the prevalence of mortality and factors associated with prolonged length of hospital stay (LOS) among dengue fever (DF) patients who were admitted at Kassala Hospital, eastern Sudan, during the ongoing war.

Methods: This hospital-based cross-sectional study of 129 hospitalized DF patients was conducted in 2025. Data on sociodemographics, clinical outcomes (recovery or death), LOS, and hematological parameters were collected using standardized methods. Univariate and multivariate Poisson regression analyses were used to identify factors associated with prolonged LOS among the recovered patients.

Results: Of the 129 hospitalized patients, 67 (51.9%) were males and their median age was 32 years. The median LOS was 4 (interquartile range, IQR 3-6) days. Twelve patients (9.3%) died and they had significantly longer LOS, elevated white blood cell (WBC), and neutrophil counts compared to recovered patients. In multivariate analysis of recovered patients, higher WBC (adjusted risk ratio, a*RR* 1.020; 95% *CI* 1.005-1.035), neutrophil (a*RR* 1.029; 95% *CI* 1.008-1.050), and lymphocyte (a*RR* 1.044; 95% *CI* 1.009-1.080) were positively associated with prolonged LOS. Other positive associations included being female sex (a*RR* 1.24; 95% *CI* 1.05-1.46), married (a*RR* 1.29; 95% *CI* 1.02-1.74), less educated (a*RR* 1.20; 95% *CI* 1.01-1.44), being a local resident (non-internally displaced person) (a*RR* 1.44; 95% *CI* 1.20-1.74), having dengue hemorrhagic fever (a*RR* 1.53; 95% *CI* 1.27-1.85), and pre-existing morbidity (a*RR* 2.18; 95% *CI* 1.71-2.78). Younger age (a*RR* 0.980; 95% *CI* 0.980-0.990), and infection with DF serotype 2 (a*RR* 0.72; 95% *CI* 0.61-0.86) or serotype 3 (a*RR* 0.51; 95% *CI* 0.30-0.87) were negatively associated.

Summary

Question: What are the mortality patterns and risk factors for prolonged hospital stays among admitted dengue fever patients in eastern Sudan during the ongoing war?

Findings: In this hospital-based cross-sectional study of 129 admitted patients, the mortality rate was 9.3%. Among those who recovered, prolonged length of hospital stay was significantly associated with female sex, lower education, local resident, dengue hemorrhagic fever, pre-existing comorbidities, and elevated white blood cell, while infection with dengue serotypes 2 or 3 was negatively associated.

Meaning: Hospitalized dengue patients face high mortality in conflict settings, requiring enhanced surveillance and targeted clinical management for high-risk individuals.

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Conclusions: The mortality rate among hospitalized dengue patients was high. Among those who recovered, prolonged LOS was associated with various clinical and sociodemographic factors. These findings highlight the need for enhanced surveillance and targeted clinical management strategies for vulnerable dengue patients in conflict-affected settings.

KEYWORDS: Dengue fever; Co-infection; Conflict; Length of hospital stay; White blood cell; Mortality; Sudan

1. Introduction

Dengue fever (DF), caused by the single-stranded RNA virus from the genus Flavivirus, is a mosquito-borne illness that represents a formidable and growing global public health challenge[1]. Transmitted primarily by the female *Aedes aegypti* mosquito, with a secondary role played by *Aedes albopictus*, dengue has become hyper endemic in over 100 countries across tropical and subtropical regions[1-3]. Dengue virus is the fastest-growing mosquito-borne disease worldwide[4]. The clinical spectrum of DF is vast, ranging from asymptomatic infection and a self-limiting febrile illness to severe and potentially fatal forms such as dengue shock syndrome (DSS) and dengue hemorrhagic fever (DHF)[1]. The global burden of dengue has escalated dramatically over recent decades[4,5]. For example, in 2024, a global worsens of dengue epidemic was reported with records of 14 million cases and 9 000 deaths, resulting in a global case fatality rate of 0.07%[4]. This increase is driven by a complex interplay of factors including climate change, urbanization, population growth, population mobility, increased global travel, vector transmission, and the breakdown of public health infrastructure in many regions[5-7]. The economic and social costs of dengue are immense, encompassing not only direct medical expenses but also lost productivity, as well as the significant burden on healthcare systems and public health services in affected countries[2,6,8].

In Africa, where dengue was once considered a minor health concern compared to other tropical diseases like malaria, its incidence has been on a sharp rise[7]. The continent has seen a substantial increase in reported cases and outbreaks, a trend that is believed to be underreported due to a lack of robust surveillance systems and diagnostic capabilities[7,9,10]. Sudan, strategically located in the Horn of Africa, is no exception to such trend. The country has faced several major dengue outbreaks in recent years, with a notable one occurring in Kassala State in eastern Sudan (the studied area) in 2019, which underscored the region's vulnerability to the disease[9,10]. These outbreaks highlight the ongoing and evolving epidemiological landscape of dengue in the country and the critical need for a deeper understanding of its local dynamics.

The present study is situated within an even more complex and challenging context, which is the ongoing war in Sudan. The impact of armed conflict on public health is profound and multi-faceted. War-torn regions often experience a catastrophic collapse of healthcare infrastructure, with hospitals and clinics becoming non-functional, destroyed, or inaccessible[11-14]. The displacement of large populations, creating internally displaced persons (IDPs) and refugees, leads to overcrowded living conditions, inadequate sanitation, and limited access to clean water, which are ideal breeding grounds for mosquito vectors[15-17]. Furthermore, the war effort diverts human and financial resources away from essential public health services, including vector control programs, disease surveillance, and community health education. This creates a perfect storm where infectious diseases including DF can spread rapidly and with devastating consequences, and where the capacity to manage and treat them is severely compromised[11-14,18]. In this environment, the clinical management of a disease like dengue, which requires careful monitoring and supportive care, becomes a significant challenge[17]. Delays in seeking medical attention due to insecurity and damaged infrastructure, combined with a lack of resources in understaffed and overwhelmed healthcare facilities, are likely to result in more severe disease presentations, higher mortality rates, and more complicated patient courses. Likewise African contexts[7,19], even before the explosion of the ongoing war, Sudan faced several health challenges[20], and an outbreak of dengue was reported among IDPs in the humanitarian camps in Darfur[17].

A crucial metric for assessing disease severity and the efficiency of healthcare delivery is the length of hospital stay (LOS). A prolonged LOS in a resource-constrained environment, particularly a conflict zone, places an immense strain on already limited resources, including hospital beds, medical supplies, and healthcare personnel[12]. Understanding the factors that contribute to a prolonged LOS is therefore essential for optimizing patient management protocols and for allocating resources effectively. Numerous studies from other endemic regions have reported various factors associated with dengue severity and prolonged hospitalization[21-29]. These factors included specific hematological markers such as low platelets, high packed cell volume (PCV), high white blood cell (WBC), low lymphocytes, co-infection with malaria, comorbidities like diabetes and hypertension, and the patient's age and clinical classification of dengue (*e.g.*, DHF and DSS)[21-29]. However, the interplay of these factors in a conflict setting, where patient demographics and access to healthcare are altered, is not well-understood. Various case fatality rates among admitted DF patients were reported by prior studies ranging from 0.58% in Mexican[22], 1.1% Malaysia[24], to 4.1% Pakistan[29]. The main reported predictors of mortality in patients admitted with DF were older age[4,30-32], prolonged LOS, high WBC, DHF and DSS[27,30-33]. It is important to mentioned that a high mortality rate of DF was reported in Kassala, eastern Sudan (6.1%), particularly among DHF and DSS cases[34].

This knowledge gap is particularly relevant to the current situation in eastern Sudan. While previous studies have confirmed the presence of dengue, there is a distinct lack of data on the clinical outcomes of admitted patients during the ongoing war. This study seeks to address this gap by providing an evidence-based assessment of the mortality patterns and the factors associated with prolonged hospitalization in a high-risk population. By focusing on patients admitted to Kassala Hospital, a key healthcare facility in a conflict-affected region, the authors and the local authorities can gain invaluable insights into the unique challenges of managing dengue in such a difficult environment. The findings will be instrumental in developing targeted clinical guidelines, improving resource allocation, and strengthening the overall public health response to dengue in Sudan. Thus, this study had two specific objectives, first, to assess the prevalence and pattern of mortality among dengue fever patients admitted to Kassala Hospital during the ongoing war, and second, to identify the factors associated with a prolonged LOS among DF patients who were admitted and subsequently discharged alive. By achieving these objectives, this study aims to contribute to a better understanding of the dengue burden in conflict-affected regions and to inform more effective and context-specific healthcare interventions.

2. Methods

2.1. Study design

This hospital-based cross-sectional study was conducted to evaluate mortality patterns and factors associated with LOS among patients admitted with DF. The study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines[35].

2.2. Setting

The study was conducted from October to December 2024 at Kassala Hospital in Kassala, eastern Sudan. This period coincides with the ongoing armed conflict in Sudan. Kassala Hospital is a primary healthcare facility in the region, currently operating under significant strain due to intermittent supply chains, limited staffing, and an increased burden of patients, including IDPs.

2.3. Participants

The study population included patients of all ages presenting to the hospital with a diagnosis of DF who required admission.

Inclusion criteria: Patients diagnosed with DF, admitted to the hospital, providing informed consent (or parental/guardian assent for minors), and having complete sociodemographic and hematological data.

Exclusion criteria: Patients treated as outpatients and those who refused to participate.

Out of 227 patients diagnosed with DF during the study period, 129 (56.8%) met the admission criteria and were recruited. The analysis of factors associated with LOS focused on the 117 patients who recovered and were discharged alive.

Definitions: Clinical classification followed WHO criteria[36]: categorizing cases into DF, DHF Grades Ⅰ - Ⅳ, and DSS. LOS was calculated in days from the time of patient's admission to the time of the discharge. While a specific cutoff for "prolonged" was not explicitly defined as a binary variable, the analysis used Poisson regression, which models count data (LOS in days). Previous studies showed different cutoffs point for defining prolonged stay (>5 days)[19,21,28], and (>3 days)[24,27,29]. Therefore, the association was with an increase in LOS rather than a fixed "prolonged" category.

2.4. Data sources and measurement

Upon admission to the hospital, comprehensive data were gathered from each participant who agreed to participate through direct patient interviews and review of the medical records. The data collection process was conducted by trained medical personnel to ensure accuracy and completeness.

Sociodemographic data: Detailed sociodemographic information was collected, including age in years, sex (male or female), residence (urban or rural), marital status (married or unmarried), occupation status (employed or unemployed), education level ("high educated level" defined as ≥secondary education or "low education level" defined as <secondary education). In addition, displacement status (IDPs/non-IDPs) was recorded whether the individual was an IDP due to the conflict or a non-IDP. This variable was crucial for understanding the impact of conflict-induced displacement.

Clinical characteristics: Co-infection with malaria, past history of dengue fever, presence of pre-existing morbidities, specifically diabetes mellitus and/or hypertension, and the outcome of the admission (recovery or death). Clinical classification of DF into classical DF, DSS, and DHF was applied according to current World Health Organization classifications.

Laboratory diagnosis: Upon admission, under aseptic conditions, a venous blood sample was collected from each patient by a qualified phlebotomist. The blood samples were immediately transported to the hospital laboratory for analysis. The diagnosis of DF was established based on standard clinical and laboratory criteria, adhering to national and international guidelines.

Dengue fever (DF): Diagnosis was confirmed by detection of dengue NS1 antigen using RDTs and/or confirmation of dengue IgM/IgG antibodies *via* ELISA, or by reverse transcription-polymerase chain reaction (RT-PCR) for dengue virus RNA where available.

Malaria: Diagnosis was confirmed by microscopic examination of Giemsa-stained thick and thin blood smears for the presence of *Plasmodium* parasites and species identification and/or by malaria RDTs detecting *Plasmodium falciparum* HRP2 antigen or *Plasmodium vivax* pLDH antigen.

Co–infection: Defined as the simultaneous confirmation of both dengue virus infection and *Plasmodium* parasite infection in the same individual using the above-mentioned diagnostic methods.

Hematological parameters measurement: Hematological parameters were measured using an automated hematology analyzer, calibrated according to the manufacturer's instructions. The following parameters were quantified and recorded: WBC count, neutrophil count, lymphocyte count, PCV, and platelet count.

Identification of dengue serotypes: DF serotypes were identified; more details are available in the prior published work[37]. Although recently, the serotype 4 was reported in Kassala eastern Sudan[38], there was no case of serotype 4 identified in this study.

2.5. Bias

To minimize selection and information bias, the study recruited all consecutive patients meeting the inclusion criteria during the study period. Data collection was performed by trained medical personnel using standardized methods and calibrated laboratory equipment to ensure the accuracy of clinical and hematological measurements.

2.6. Study size

Based on previous guidelines[39], an *a priori* power analysis was conducted to determine the sample size requirement. Assuming a simple correlation of r=0.25 between the LOS of DF and independent continuous factors such as age, and WBC, a minimum sample size of 129 participants was calculated as necessary to achieve a 5% significance level (α=0.05) and 80% power. Separately, as detailed in Section 3.1, our clinical selection process filtered the initial pool of 227 diagnosed patients down to a final sample size of 129 patients who met all eligibility criteria. Thus, our final sample size successfully satisfies the minimum statistical power requirement.

2.7. Quantitative variables

Outcome variables: The primary outcomes were the admission outcome (recovery or death) and the LOS, measured in days from admission to discharge.

Independent variables: Sociodemographic factors (age, sex, residence, marital status, education level, occupation, and displacement status), clinical characteristics (pre-existing morbidities like diabetes/hypertension, past history of DF, and clinical classification of DF), and hematological parameters.

2.8. Statistical methods

The collected data were entered into IBM Statistical Product and Service Solutions (SPSS) for Windows (version 22.0; SPSS Inc., New York, NY) for analysis. Continuous data such as age, WBC, PCV, platelets, and LOS were tested using the Kolmogorov–Smirnov test and they were found to be not-normally distributed. Consequently, they were expressed as median [interquartile range (IQR)]. The Mann-Whitney *U* test was used to compare the differences in not-normally distributed variables including age, and hematological parameters between patients who recovered and those who died. The *Chi*-square test was used to compare categorical variables between these two groups. Furthermore, modified univariate Poisson-regression analyses were applied with LOS among admitted patients who recovered as the dependent variable and sociodemographic (age, sex, marital status, residence, IDPs, education, and occupation), preexisting morbidity with diabetes mellitus and/or hypertension), DF related factors (past history of DF), hematological parameters (WBC, neutrophil, PCV, and platelets), as the independent variables. Initially, univariate Poisson-regression analysis was performed and variables with their *P* value of <0.20 were shifted to build a multivariate Poisson regression to model the LOS and provide the adjusted relative risk (a*RR*) values and 95.0% confidence intervals (*CI*s). Goodness-of-fit and model diagnostics were systematically evaluated for the multivariate Poisson regression model. The resulting Deviance/Degrees of Freedom ratio was close to 1.0, establishing the absence of significant over dispersion and validating the choice of model for the length of stay data. A *P*-value of $P<0.05$ was considered significant.

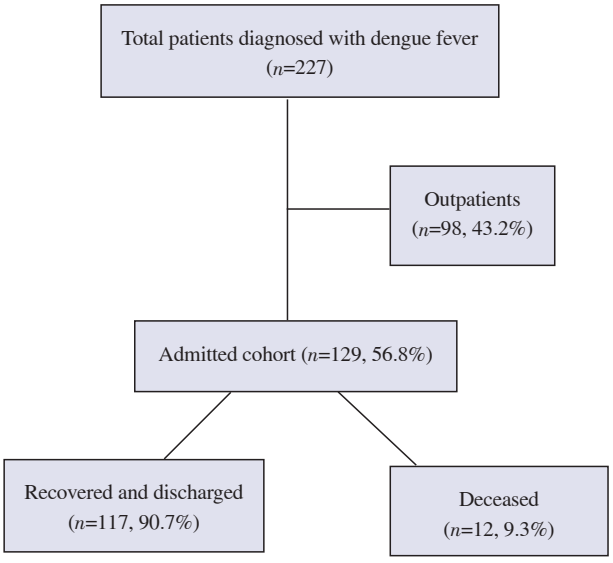

Figure 1. Flowchart of study participants and clinical outcomes of the dengue fever patients.

3. Results

3.1. Participants

During the study period, a total of 227 patients were diagnosed with dengue fever, of whom 129 (56.8%) were admitted to the hospital for further evaluation and management, while the remaining 98 (43.20%) were treated as outpatients. Among those admitted (n=129), 117 (90.7%) recovered and were discharged alive, while 12 patients (9.3%) died during hospitalization (Figure 1).

3.2. Descriptive data

Of the 129 admitted patients, 67 (51.9%) were male and 62 (48.1%) were female, with a median age (IQR) of 32.0 (22.0-53.5) years. Sociodemographic analysis showed that 83 (64.3%) resided in urban areas, 68 (52.7%) were married, 68 (52.7%) were IDPs, 68 (52.7%) had a high education level (≥ secondary), and 37 (28.7%) were formally employed. Clinical baseline data revealed that 44 (34.1%) had malaria co-infection, 17 (13.2%) had a past history of DF, and 20 (15.5%) had pre-existing morbidities (diabetes mellitus and/or

Table 1. General characteristics of the total patients admitted with dengue fever at Kassala Hospital during the ongoing war in Sudan 2024 (N=129).

Variable	Total (n=129)	Admission outcome		P value
		Death (n=12)	Recovery (n=117)	
Age, years, median (IQR)	32.0 (22.0-53.5)	28.5 (23.2-63.7)	32.0 (22.0-53.0)	0.546
White blood cell, $\times10^9$/L, median (IQR)	4.4 (2.8-6.5)	8.3 (3.8-15.9)	4.2 (2.6-5.9)	0.010
Neutrophil cell, $\times10^9$/L, median (IQR)	2.4 (1.4-4.2)	5.2 (2.5-13.5)	2.3 (1.3-3.7)	0.004
Lymphocyte cell, $\times10^9$/L, median (IQR)	1.3 (0.7-2.2)	1.3 (1.0-2.1)	1.3 (0.7-2.1)	0.786
Packed cell volume, %, median (IQR)	36.6 (32.6-40.3)	36.7 (33.2-39.4)	36.6 (32.2-40.4)	0.906
Platelets, $\times10^9$ /L, median (IQR)	115.0 (60.0-186.0)	103.0 (31.5-169.5)	115.0 (61.5-190.0)	0.229
Length of stay, days, median (IQR)	4.0 (3.0-6.0)	6.0 (4.0-10.8)	4.0 (3.0-5.0)	0.001
Sex, n (%)				
Male	67 (51.9)	7 (58.3)	60 (51.3)	0.642
Female	62 (48.1)	5 (41.7)	57 (48.7)	
Residence, n (%)				
Urban	83 (64.3)	8 (66.7)	75 (64.1)	0.860
Rural	46 (35.7)	4 (33.3)	42 (35.9)	
Internal displaced persons (IDPs), n (%)				
Non-IDPs	61 (47.3)	1 (8.3)	60 (51.3)	0.005
IDPs	68 (52.7)	11 (91.7)	57 (48.7)	
Marital status, n (%)				
Married	68 (52.7)	6 (50.0)	62 (53.0)	0.843
Unmarried	61 (47.3)	6 (50.0)	55 (47.0)	
Education level, n (%)				
Secondary	68 (52.7)	6 (50.0)	62 (53.0)	0.843
<Secondary	61 (47.3)	6 (50.0)	55 (47.0)	
Occupation status, n (%)				
Employed	37 (28.7)	6 (50.0)	31 (26.5)	0.086
Unemployed	92 (71.3)	6 (50.0)	86 (73.5)	
Pre-existing morbidity with diabetes mellitus and/or hypertension, n (%)				
No	109 (84.5)	11 (91.7)	98 (83.8)	0.471
Yes	20 (15.5)	1 (8.3)	19 (16.2)	
Co-infection with malaria, n (%)				
Yes	44 (34.1)	6 (50.0)	38 (32.5)	0.223
No	85 (65.9)	6 (50.0)	79 (67.5)	
History of dengue fever, n (%)				
No	112 (86.8)	9 (75.0)	103 (88.0)	0.204
Yes	17 (13.2)	3 (25.0)	14 (12.0)	
Clinical classification of dengue fever, n (%)				
Classic dengue fever	74 (57.4)	3 (25.0)	71 (60.7)	0.037
Dengue hemorrhagic fever	42 (32.6)	6 (50.0)	36 (30.8)	
Dengue shock syndrome	13 (10.1)	3 (25.0)	10 (8.5)	
Dengue fever serotype, n (%)				
Serotype 1	4 (3.1)	0 (0.0)	4 (3.4)	0.127
Serotype 2	84 (65.1)	11 (91.7)	73 (62.4)	
Serotype 3	41 (31.8)	1 (8.3)	40 (34.2)	

The Mann-Whitney U test was used to compare data expressed as median (IQR), and Chi-square test for n (%).

hypertension). Baseline hematological medians (IQR) were: WBC 4.4 (2.8-6.5) $\times 10^9$/L, neutrophils 2.4 (1.4-4.2) $\times 10^9$/L, lymphocytes 1.3 (0.7-2.2) $\times 10^9$/L, PCV 36.6% (32.6-40.3), and platelets 115.0 (60.0-186.0) $\times 10^9$/L (Table 1).

3.3. Outcome data

The primary outcomes measured were mortality and LOS. The overall mortality rate among all diagnosed patients (12/227) was 5.3%, rising to 9.3% (12/129) among the admitted cohort. For those who were discharged, the median LOS was 4 (IQR 3-6) days, with a range of 1 to 36 days and a 90th percentile of 8 days.

3.4. Main results

Univariate Poisson analysis showed that age, WBC, neutrophil and lymphocyte counts, platelets, PCV, sex, IDP status, marital status, education, pre-existing morbidity, clinical classification, and dengue serotypes were associated with LOS. In the multivariate Poisson analysis, prolonged LOS was positively associated with higher WBC counts (a*RR* 1.020; 95% *CI* 1.005-1.035), neutrophil counts (a*RR* 1.029; 95% *CI* 1.008-1.050), lymphocyte counts (a*RR* 1.044; 95% *CI* 1.009-1.080), female sex (a*RR* 1.24; 95% *CI* 1.05-1.46), being married (a*RR* 1.29; 95% *CI* 1.02-1.62), lower education (a*RR* 1.20; 95% *CI* 1.01-1.44), being a local resident (non-IDPs) (a*RR* 1.44; 95% *CI* 1.20-1.74), DHF (a*RR* 1.53; 95% *CI* 1.27-1.85), and

Table 2. Univariate and multivariate Poisson regression analyses of factors associated with length of stay by patients with dengue fever at Kassala Hospital, eastern Sudan, during the ongoing war 2024 (*n*=117).

Variable*	Univariate analysis		Multivariate analysis	
	RR (95% *CI*)	*P* value	a*RR* (95% *CI*)	*P* value
Age, years	1.004 (1.000-1.008)	0.047	0.980 (0.980-0.990)	<0.001
White blood cell, $\times 10^9$/L	1.020 (1.005-1.035)	0.008	1.020 (1.004-1.042)	0.019
Neutrophil cell, $\times 10^9$/L	1.029 (1.008-1.050)	0.006	1.032 (1.005-1.060)	0.020
Lymphocyte cell, $\times 10^9$/L	1.044 (1.009-1.080)	0.014	1.044 (1.002-1.087)	0.038
Packed cell volume, %	0.980 (0.970-0.990)	<0.001	0.993 (0.98-1.003)	0.156
Platelets, $\times 10^9$/L	1.001 (1.000-1.002)	0.007	1.000 (0.999-1.001)	0.621
Sex				
Male	Reference			
Female	1.29 (1.10-1.52)	0.002	1.24 (1.05-1.46)	0.012
Residence				
Rural	Reference			
Urban	1.01 (0.85-1.19)	0.882	-	-
Internal displaced persons (IDPs)				
IDPs	Reference			
Non-IDPs	1.29 (1.10-1.53)	0.002	1.44 (1.20-1.74)	<0.001
Marital status				
Unmarried	Reference			
Married	1.31 (1.11-1.55)	0.001	1.29 (1.02-1.62)	0.031
Education level				
Secondary	Reference			
<Secondary	1.48 (1.26-1.75)	<0.001	1.20 (1.01-1.44)	0.043
Occupation status				
Employed	Reference			
Unemployed	0.93 (0.78-1.12)	0.485	-	-
Co-morbidity with diabetes mellitus and/or hypertension				
No	Reference			
Yes	1.83 (1.52-2.20)	<0.001	2.18 (1.71-2.78)	<0.001
Co-infection with malaria				
No	Reference			
Yes	0.99 (0.83-1.18)	0.954	-	-
History of dengue fever				
No	Reference			
Yes	0.91 (0.70-1.18)	0.505	-	-
Clinical classification of dengue fever				
Classic dengue fever	Reference			
Dengue hemorrhagic fever	1.68 (1.30-2.17)	<0.001	1.53 (1.27-1.85)	<0.005
Dengue shock syndrome	1.31 (1.10-1.57)	0.002	1.18 (0.89-1.57)	0.225
Dengue fever serotype				
Serotype 1	Reference			
Serotype 2	0.67 (0.57-0.80)	<0.001	0.72 (0.61-0.86)	<0.001
Serotype 3	0.62 (0.37-1.04)	0.071	0.51 (0.30-0.87)	0.013

-: Multivariate analysis not conducted.

pre-existing morbidity (a*RR* 2.18; 95% *CI* 1.71-2.78). Conversely, younger age (a*RR* 0.98; 95% *CI* 0.98-0.99) and infection with DF serotypes 2 (a*RR* 0.72; 95% *CI* 0.61-0.86) or 3 (a*RR* 0.51; 95% *CI* 0.30-0.87) were negatively associated with prolonged LOS, while PCV and platelets were identified as confounding factors (Table 2, and Supplementary Figure 1).

3.5. Other analyses

Comparative analysis showed significant differences between patients who died and those who recovered; deceased patients were more likely to have a longer LOS [median 6.0 (4.0-10.8) *vs.* 4.0 (3.0-5.0) days], higher WBC [8.3 (3.8-15.9) *vs.* 4.2 (2.6-5.9) $\times 10^9$/L], and higher neutrophil counts [5.2 (2.5-13.5) *vs.* 2.3 (1.3-3.7) $\times 10^9$/L] ($P<0.05$) (Table 1). In addition, Chi-square testing confirmed significant differences in admission outcomes regarding IDP status and clinical classification of DF ($P<0.05$), while no significant differences were found for sex, residence, education, occupation, history of DF, malaria co-infection, or pre-existing morbidity (Table 1).

4. Discussion

This study provides a crucial and timely assessment of the mortality patterns and factors associated with prolonged hospital stays among DF patients in eastern Sudan, amidst the challenging backdrop of the ongoing war. The findings elucidate the unique epidemiological and clinical dynamics of dengue in a conflict-affected setting, where a collapsed health system and displaced populations intersect with a burgeoning infectious disease burden. The results highlight a concerning mortality rate and identify several key clinical and sociodemographic factors that independently influence patient outcomes and the length of hospitalization. This discussion delves into these findings, contextualizing them within global literature and exploring their implications for clinical management and public health policy in similar crises.

A principal finding of this study is the alarmingly high prevalence of mortality among admitted patients, with a case fatality rate of 9.3%. This prevalence is significantly higher than the rates reported in numerous other endemic regions, which typically range from < 1% to around 4%[22,24,29]. In contrast, a higher mortality rates was reported. In Brazil among dengue patients admitted in-ICU 18.6%[32], which could be explained by the severity of the admitted patients. The elevated mortality rate in this study is not surprising given the context of the ongoing war in Sudan. The conflict has led to a catastrophic breakdown of healthcare infrastructure, with a significant portion of hospitals and clinics rendered non-functional or inaccessible[11-14]. This creates a domino effect: patients often experience significant delays in seeking medical care due to insecurity and damaged transport routes, leading to presentation at the hospital with a more advanced or severe form of the disease. Furthermore, the hospital's capacity to provide timely and comprehensive supportive care, a cornerstone of effective dengue management, is severely compromised by intermittent supply chains for essential medical resources, a shortage of trained personnel, and an overwhelming patient load, including IDPs and non-IDPs alike. The finding that deceased patients had a significantly longer median LOS, as well as higher WBC and neutrophil, further supports this narrative. These markers are indicative of a severe, prolonged inflammatory response, often associated with a complicated disease course, multiple organ involvement, and a poorer prognosis[33]. It is important to mentioned that, the overall mortality among all treated patients (outpatients and admitted patients, n=227) was 5.3%, it is similar to the previous reported in Kassala (6.1%)[34].

This observed mortality rate underscores the urgent need for humanitarian and public health interventions to stabilize healthcare services in conflict zones and to implement early-warning systems for outbreaks of infectious diseases like dengue.

Beyond mortality, the study's primary objective was to identify factors associated with prolonged LOS among patients who recovered a critical metric for understanding disease severity and resource utilization in a resource-constrained setting. In the multivariate Poisson regression analysis, several independent predictors emerged, offering a detailed picture of the clinical and demographic risk factors in this population.

The positive association of higher WBC (a*RR*=1.02), neutrophil (a*RR*=1.03), and lymphocyte counts (a*RR*=1.044) with prolonged LOS is a significant and nuanced finding. While a hallmark of dengue is often leukopenia (low WBC) in the early stages, an increase in these counts, particularly neutrophil, can indicate a robust inflammatory response or, more critically, a secondary bacterial co-infection. This study's high prevalence of co-infection with malaria (34.1%) provides a plausible explanation. Co-infection with other pathogens, especially malaria, is known to complicate the clinical picture of dengue, leading to a more severe disease, altered hematological profiles, and longer hospitalization periods due to the need to manage both infections simultaneously[40].

This finding aligns with research from other regions including eastern Sudan where tropical co-infections are common and underscores the importance of differential diagnosis and co-infection management in endemic areas, particularly during an outbreak in a war-affected zone. For instance, the author prior study revealed a high co-infection dengue with malaria in the eastern Sudan[34]. Interestingly, the analysis showed that while PCV and platelets were significantly different between the recovery and death groups

in the univariate analysis, they became confounding factors in the multivariate model for LOS. This suggests that their effect on hospitalization duration is likely mediated through other more direct indicators of systemic inflammation or clinical severity, a point that warrants further investigation with a larger, more powered study. For example, severe thrombocytopenia may be a key driver of complications that lead to death, but not necessarily a direct cause of prolonged stay in those who recover, especially if platelet counts recover quickly. Similarly, a high PCV, indicative of plasma leakage, is a key diagnostic criterion for severe dengue but its effect on LOS might be more transient than the sustained inflammatory markers.

Sociodemographic factors also played a significant role in predicting prolonged LOS. Being female (a*RR*=1.24), married (a*RR*=1.29), and having a lower education level (a*RR*=1.20) were all independently associated with a longer stay. These findings are likely a reflection of complex socioeconomic and cultural dynamics within the study area and are consistent with health disparities observed globally. In many patriarchal societies, women, particularly if married, may face significant barriers to accessing timely medical care due to their domestic responsibilities, financial dependency, or social constraints, leading to a delay in seeking treatment and a more severe illness upon presentation[8,41]. Similarly, lower educational attainment is often a proxy for lower socioeconomic status, which can be linked to poor living conditions, limited health literacy, and delayed healthcare-seeking behaviors, all of which are known risk factors for adverse health outcomes in dengue[23]. The negative association between younger age and prolonged LOS (a*RR*=0.98) is also notable, suggesting that older patients in the study cohort, who may have higher rates of comorbidities, required longer hospitalization. This aligns with global trends where older age is often a risk factor for severe dengue and its complications, though our study's effect size is small, possibly due to a relatively young median age in the cohort[23]. This study explored the vulnerability of IDPs to dengue including morbidity (prolonged LOS) and mortality. This aligns with several studies that emphasize the vulnerability of IDPs to infectious diseases including Dengue[17,42]. Xu *et al.*, attributed such vulnerability to dengue infection to the lack of knowledge among IDPs compared the local citizens[42]. Besides, the environmental and living conditions vulnerability of IDPs, lack of immunity and undernutrition among the IDPs could contribute to their severity of DF compared to the local citizens. In contrast to this study, other studies reported older age[30,31,33], residence[31], sex, and the presence of co-morbidity[31], were associated with dengue mortality. Also, in compared to previous studies[29-31,33], in this study age was not associated with morality and being younger was more likely to have prolonged LOS. Such lack of association can be used as a driver to further research to explore the impact of displacement on the classical sociodemographic factors that associated with dengue infection.

In this study co-infection with malaria was not associated mortality and prolonged LOS. Other studies addressed the poor outcomes of co-infection compared to mono-infection[43,44]. The lack of association in this study could be explained by delay referral of such cases (co-infected) to healthcare facilities and as a result died in the community.

The study also supported the well-established association between certain clinical factors and severe dengue outcomes. The presence of DHF (a*RR*=1.53) and pre-existing morbidities such as diabetes and/or hypertension (a*RR*=2.18) were found to be powerful predictors of a prolonged LOS. These findings are consistent with the known pathophysiology of dengue, where pre-existing conditions can compromise the patient's physiological reserves and immune response, making them more susceptible to the severe manifestations of the disease, such as plasma leakage and shock[24,26,28].

Patients with these risk factors require more intensive monitoring, fluid management, and supportive care, thereby increasing their time in the hospital. The strong association with pre-existing morbidity highlights the need for targeted clinical protocols for high-risk patients, especially in a resource-limited setting.

A particularly interesting finding is the negative association of DF serotype 2 (a*RR*=0.72) and serotype 3 (a*RR*=0.51) with prolonged LOS compared to serotype 1. This result appears to contradict some global literature, which frequently identifies serotype 2 as a major cause of severe dengue outbreaks and heightened virulence[15,16]. However, the local epidemiology of dengue serotypes can be highly volatile. The reasons for this discrepancy are not immediately clear but could be attributed to several factors. It is possible that the dominant serotype causing the most severe cases in this specific outbreak was not DENV-2 or DENV-3 (serotype 1 or other undiscovered yet serotypes), presence of other undiagnosed acute febrile illnesses, shifting of the these serotypes (DENV-2 and/or DENV-3) to mortality rather than prolonged LOS, or that the population in Kassala has a unique immunological history that has shaped its response to these serotypes[37]. For instance, prior exposure to a particular serotype might offer some cross-protection, or a different serotype altogether could be driving the most severe cases. The concept of antibody-dependent enhancement (ADE), where a secondary infection with a different serotype can lead to more severe disease, might also play a role, but needs more detailed serological data to confirm. Given the context of war and population displacement, the epidemiological dynamics of dengue serotypes could be highly localized and subject to rapid change. This finding underscores the need for continuous serological and genomic surveillance to inform public health strategies.

The strengths of this study lie in its focus on a population and context that have been largely under-researched. By providing

evidence from a conflict-affected zone, this research provides a unique contribution to the global understanding of dengue epidemiology. The use of a robust statistical method like Poisson regression for analyzing count data (LOS) is also strength. However, the study is not without limitations, which need to be acknowledged to improve future research. Its cross-sectional design prevents the establishment of causal relationships. As a single-center, hospital-based study, the findings may not be generalizable to the entire population of eastern Sudan or to those who received outpatient care, as this study's cohort represents a more severe subset of cases. The sample size, while sufficient for detecting some associations, may have been underpowered to detect other, more subtle relationships. Additionally, detailed clinical data regarding pre-admission outpatient medications and the exact number of days from symptom onset to hospital admission were not captured in our dataset, which may introduce unmeasured confounding regarding hospital LOS. Finally, from the common acute febrile illnesses, DF and malaria were investigated, present of other acute febrile illnesses such as Chikungunya virus "Kankasha" cannot be ruled out[45].

In conclusion, the study highlights a high mortality rate among hospitalized dengue patients in Kassala, eastern Sudan, during the ongoing war. Prolonged LOS was associated with higher inflammatory markers, specific sociodemographic factors (female, married, less educated), DHF, and pre-existing comorbidities. These results provide vital, context-specific evidence for guiding clinical management and public health interventions. Moving forward, there is a critical need for longitudinal, multi-center studies to validate these findings and to better understand the long-term outcomes and serological dynamics of dengue in conflict-affected regions. The findings suggest that in such settings, clinical protocols must prioritize early identification of high-risk patients, especially those with comorbidities or specific hematological markers, and should be tailored to account for the unique challenges of a strained healthcare system.

Conflict of interest statement

The authors have no competing interests to declare.

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Data availability

The data of the present study are available from the corresponding author upon reasonable request.

Ethics approval and consent from participants

All study procedures and data collection methods were conducted in strict accordance with the ethical principles outlined in the Declaration of Helsinki. The study received the ethics approval from the ethical board of the Health Research Ethics Committee, Ministry of health, Kassala state, Kassala, Sudan, under reference (No.28) on 20 May 2023. All participants (or their legal guardians for minors) signed a written informed consent form. The authors followed all measures to ensure the privacy and confidentiality of the participants, including excluding personal identifiers during data collection. All patients diagnosed by DF were treated in the same manner regardless of their participation.

Authors' contributions

Conceptualization: AOM, TMA, AA, Data curation: AOM, TMA, AHK, AMA, Laboratory investigations and methodology: RWFO, WME, and SAAM. Data analysis and preparation of tables: AOM, Project administration and supervision: TMA, AOM, Funding acquisition: TMA, Writing the initial draft: AOM, AA, ASH, and TMA, Reviewing and editing the final draft: AAH, and ASH. All authors have reviewed and approved the final manuscript. All authors have read and agreed to the published version of the manuscript.

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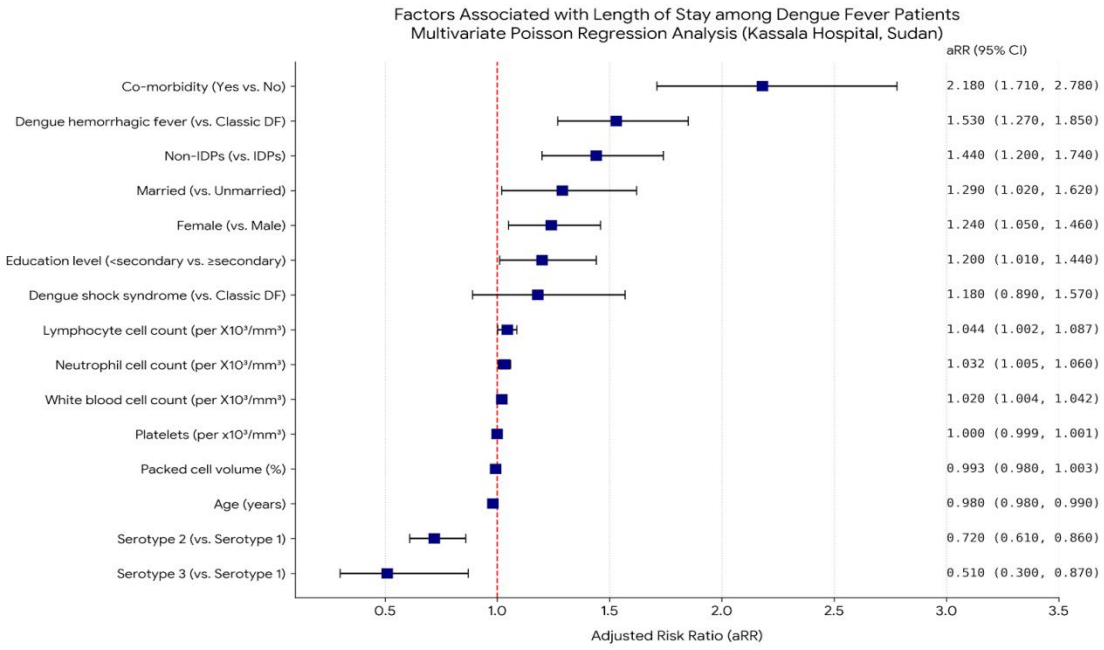

Supplementary Figure 1. Forest plot of adjusted risk ratios (a*RR*) and 95% confidence intervals (*CI*s) for factors associated with length of hospital stay among recovered dengue fever patients (*n*=117). *Note:* The vertical red dashed line at 1.0 represents the null hypothesis (no statistical effect). Point estimates to the right of the line signify factors that independently prolong hospitalization, while point estimates to the left represent factors associated with a shorter length of stay.