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ORIGINAL ARTICLE

The effect of war on displaced hemodialysis patients in Sudan

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ABSTRACT

BACKGROUND

The Sudan war has severely disrupted healthcare services, particularly for patients with end-stage renal disease (ESRD) dependent on regular hemodialysis. Conflict-related displacement, damaged infrastructure, medication shortages, and financial hardship have compromised dialysis continuity and patient outcomes. This study assessed the impact of war-related displacement on dialysis care among Sudanese hemodialysis patients.

METHODS

This cross-sectional observational study included 101 displaced ESRD patients receiving maintenance hemodialysis. Data collection comprised demographic characteristics, causes of ESRD, dialysis access and adequacy, treatment interruptions, complications, medication availability, hospital admissions, and functional status before, during, and after the war. Comparisons of dialysis parameters and functional status before, during, and after the war were performed using Cochran's Q test.

RESULTS

War-related displacement was associated with statistically significant worsening of dialysis care. Dialysis frequency decreased from two to 1.5 sessions per week, and session duration declined from four to three hours (both $p<0.05$). Patients missed a median of one dialysis session per week. Consequently, out-of-pocket payment for medications surged from 42 (41.6%) pre-war to 93 (92.1%) during the war and persisted at 89 (88.1% in the current period ($p<0.0001$). Erythropoietin use declined from 98 (97.1%) to 39 (38.6%) (both at $p<0.001$). Displacement was also associated with significantly increased complications, hospitalizations, reduced medication adherence, and marked fatigue ($p < 0.05$).

CONCLUSION

War-related displacement significantly reduced dialysis adequacy, medication access, and continuity of care, resulting in increased morbidity. Immediate humanitarian and health-system interventions are essential to prevent excess mortality among displaced hemodialysis patients.

Keywords: Displacement; healthcare disruption; hemodialysis complications; humanitarian aid; Sudan-war

INTRODUCTION

On 15 April 2023, Sudan experienced a severe escalation of armed conflict, characterized by heavy weaponry and aerial bombardments, between the Sudanese Armed Forces (SAF) and the paramilitary Rapid Support Forces (RSF). This confrontation has precipitated the displacement of approximately 8 million individuals, encompassing internally displaced persons (IDPs), asylum seekers, and refugees. The hostilities have exacerbated pre-existing structural vulnerabilities in Sudan, including chronic political and economic instability, recurrent disease outbreaks, persistent social unrest, and environmental crises. The United Nations reports that nearly 50% of the population (24 million people) now require urgent humanitarian assistance and protection. The humanitarian landscape has deteriorated markedly, with acute shortages of food, potable water, essential medicines, and fuel.[1] Approximately 18 million individuals are experiencing severe food insecurity. Since the onset of hostilities, over 13,000 fatalities and 26,000 injuries have been documented.[2] Maternal mortality rates are critically elevated, driven by unassisted home deliveries and the paucity of emergency obstetric care.[3] Malnutrition and neonatal mortality remain pressing public health concerns.[4] The ongoing hostilities have inflicted substantial damage on existing healthcare infrastructure, overwhelming facilities and severely impeding access to essential medical services. During armed conflicts, individuals with renal disorders, whether residing in affected regions or being displaced, experience significantly elevated risks due to both medical and logistical challenges. Acute kidney injury (AKI), whether occurring in combat zones, field hospitals, or tertiary care facilities, is associated with poor clinical outcomes.[5] Patients with chronic kidney disease (CKD) are particularly vulnerable to interruptions in routine care, which may exacerbate disease progression.[6] Individuals requiring dialysis or organ transplantation face substantial barriers in accessing dialysis services or immunosuppressive therapies, thereby increasing the risk of severe complications, including mortality. Interventions aimed at mitigating these risks are often only partially effective. Strengthening local preparedness for both general and healthcare-specific disaster response is therefore critical. Given the limitations in medical supplies, strategic adjustments, such as modifying dialysis frequency or modality, transitioning between hemodialysis and peritoneal dialysis, and tailoring immunosuppressive regimens, may be necessary to optimize patient outcomes.

Recent conflicts, including those in Ukraine, Gaza, and Sudan, have stressed these challenges. In Ukraine, international support coordinated by global kidney care organizations helped sustain dialysis and transplant services for thousands of patients, including those displaced to neighboring European countries.[7] In contrast, Gaza and Sudan experienced severe shortages, overwhelmed dialysis facilities, unsafe working conditions, and mass displacement that further strained already fragile health systems, resulting in preventable deaths among dialysis and transplant patients.[8]

Healthcare professionals in Sudan have been compelled to confront profound ethical and clinical dilemmas, frequently unable to deliver urgent care to patients in need. A joint statement issued by the American Society of Nephrology (ASN), the European Renal Association (ERA), and the International Society of Nephrology (ISN) highlighted acute concern for individuals with renal impairment amid the ongoing conflict. It is estimated that approximately 8,000 patients in Sudan rely on hemodialysis for survival.[9] Severe shortages of essential dialysis supplies pose substantial threats to patients' lives, particularly in regions directly affected by hostilities. In Khartoum, where even prior to the conflict, the number of operational dialysis centers was limited, the ongoing war has further compromised their functionality due to security risks, disrupted medical supply chains, and recurrent electrical outages.[10] The resultant scenario constitutes a humanitarian catastrophe, with continuous loss of patients' lives and inadequate management of deceased individuals. These highlight a significant global gap in preparedness and response strategies for renal replacement therapy during humanitarian crises. Although several situation-specific reports exist, there remains limited consolidated evidence on the overall impact of war on kidney care and on the effectiveness of global aid mechanisms. Given the limited understanding of the current and potential impacts of the conflict on the healthcare of hemodialysis patients, this study aimed to provide critical evidence to inform policy

responses. By generating empirical data, or at least establishing a baseline, the research seeks to guide decision-making, support advocacy efforts, and enhance public awareness regarding the healthcare needs of hemodialysis patients in Sudan. Previous studies from Sudan and other conflict-affected regions consistently demonstrate that armed conflict severely disrupts hemodialysis services, though the emphasis and outcomes vary. A multicenter Sudanese study by Idrees et al.[11] reported that more than half of patients were unable to maintain regular dialysis, with high rates of anxiety, depression, reduced healthcare affordability, and impaired quality of life. Similar findings from conflict settings in Syria, Yemen, and Ukraine showed reduced dialysis frequency, infrastructure damage, shortages of supplies, and increased complications, although many studies relied on descriptive or psychosocial outcomes rather than clinical metrics.[12] Overall, the evidence is largely consistent in demonstrating treatment disruption and worsening patient outcomes, with limited inconclusive findings. Unlike prior studies that primarily focused on mental health, access frameworks, or quality of life, our study uniquely quantifies dialysis adequacy parameters**,** medication availability (erythropoietin), and out-of-pocket costs, highlighting direct morbidity and providing clinically actionable data for humanitarian response. Our study provides novel evidence on the direct clinical consequences of war-related displacement on hemodialysis care in Sudan. Unlike Idrees et al.,[11] who emphasized psychological distress and healthcare access, we quantitatively demonstrate dialysis inadequacy, reduced session frequency and duration, loss of erythropoietin access, increased out-of-pocket costs, and higher morbidity using real-world hospital-based data.

METHODS

Research design

This was an observational, cross-sectional, hospital-based study conducted at Atbara Teaching Hospital, located in the Nile State of Sudan between May–August 2024.

Study setting and research subjects

The above-named hospital became a major receiving facility following the collapse or inaccessibility of dialysis units in conflict-affected regions, particularly Khartoum. The study population consisted of all adult hemodialysis patients with ESRD who had been displaced due to the ongoing Sudanese war and were attending the dialysis unit at Atbara Teaching Hospital during the study period (May–August 2024). Eligible participants were adults aged 18 years or older undergoing regular maintenance hemodialysis and willing to provide informed consent. Patients were excluded if they (i) were receiving hemodialysis for non-ESRD indications, and (ii) were not displaced due to the war.

Sample size and sampling

Given the exceptional circumstances of mass displacement and the limited number of patients concentrated at the receiving center, a total coverage sampling strategy was employed. All displaced adult ESRD patients who presented to Atbara Teaching Hospital during the study period and met the inclusion criteria were enrolled, yielding a final sample of 101 participants. The inclusion criteria were: (i) adult patients aged ≥18 years; (ii) diagnosed with end-stage renal disease (ESRD); (iii) receiving maintenance hemodialysis at Atbara Teaching Hospital;(iv) displaced due to the ongoing Sudanese war and relocated from conflict-affected areas;(v) attending the dialysis unit during the study period (May–August 2024), and (vi) able and willing to provide informed consent. The exclusion criteria were: (i) patients receiving peritoneal dialysis or conservative (non-dialytic) management and (ii) critically ill patients unable to participate in the interview or data collection. This approach ensured maximum representation of the displaced hemodialysis population served by the facility, minimized selection bias, and provided a realistic reflection of the operational burden experienced by the center during the conflict.

Data collection

Data were collected through direct face-to-face interviews conducted by trained members of the research team. A structured, closed-ended questionnaire with one open-ended item was used for patient assessment and consisted of 127 items covering demographic characteristics, comorbidities, frequency and duration of dialysis before and during displacement, missed sessions, financial burden, medication access, dialysis complications, vascular access problems, and perceived health status.

Instruments of measurement

The structured interview questionnaire was specifically designed to assess the multidimensional impact of war and displacement on hemodialysis patients. The instrument incorporated both close and open ended items and was organized into five major domains: (i) demographic and socioeconomic characteristics; (ii) access to healthcare services;(iii) physical implications of dialysis disruption; (iv) psychological status; and (v) health-related quality of life. Demographic variables included age, sex, marital status, education, employment, comorbidities, income source, expenditure, and housing conditions before and after displacement. Healthcare access was evaluated using Levesque's Conceptual Framework of Access, which examines approachability, acceptability, availability/accommodation, affordability, and appropriateness on a 0–10 scale, with scores below five indicating poor access.[13] The physical implications domain assessed trauma exposure, missed dialysis sessions, changes in dialysis frequency and duration, and acute complications resulting from treatment interruption. Psychological assessment employed validated screening tools, namely generalized anxiety disorder-2 (GAD-2) for generalized anxiety and patient health questionnaire-2 (PHQ-2) for depressive symptoms, that were selected for their strong sensitivity, specificity, and suitability in crisis settings.[14] Quality of life was measured using the kidney disease and quality of life-36 (KDQOL-36) questionnaire, which evaluates physical and mental functioning, symptom burden, effects and perceived burden of kidney disease, and related cognitive function.[15] Together, these measurement tools provided a comprehensive and methodologically robust evaluation of the clinical, psychosocial, and functional consequences of war on displaced patients receiving maintenance hemodialysis.

Statistical analysis

Comparisons across the three time points (before, during, and after the war) involved repeated measurements on the same individuals; thus, the data were treated as paired observations. Descriptive statistics, including means, medians, interquartile ranges, frequencies, and percentages, were used to summarize demographic characteristics, dialysis parameters, medication access, complications, and hospitalization rates. Continuous variables were assessed for distributional properties to determine whether parametric or nonparametric summaries were appropriate, particularly for dialysis frequency, session duration, and financial burden. Categorical variables were summarized using frequencies and percentages to describe the prevalence of missed sessions, vascular access issues, intradialytic complications, and limitations in accessing nephrology services. Psychological outcomes were quantified using validated scoring algorithms for GAD-2 and PHQ-2, and quality of life was evaluated using KDQOL-36 composite scores. Healthcare access dimensions derived from Levesque's conceptual framework were analyzed to identify the most affected domains during the conflict. Because the same participants were assessed before, during, and after the war, observations were paired rather than independent, and several outcomes were binary (yes/no). Therefore, comparisons across the three related time points were performed using Cochran's Q test. A p-value <0.05 was considered statistically significant.

Ethical considerations

This study adhered to stringent ethical guidelines for research involving human subjects. Ethical approvals were obtained from the Faculty of Medicine, Nile Valley University, Sudan, and the Atbara Teaching Hospital, Sudan (Approval number: NVU1224-014). Written informed consent was obtained from all participants, who had the right to withdraw at any time. Patient confidentiality was maintained through secure data storage, with access limited to authorized personnel.

RESULTS

Demographic characteristics

This study involved 101 patients who were displaced to Atbara, Sudan, due to ongoing war, predominantly from Khartoum state, with mean age of 46 years, and included 51% male and 49% female participants (Table 1).

Hemodialysis treatment disruptions

In our study, the duration of having been on dialysis varied, with 37% having been on dialysis for 1-5 years, 31% for 6-10 years, and 16% for about one year (Table 2). Most participants (79%) relied on an arteriovenous fistula (AVF) for dialysis access, and 22% of them used a permcath. During dialysis sessions, hypoglycemia (22%) and

hypotension (20%) were the most common complications. Considering causes of hospital admission after displacement, the most common causes were fluid overload (21%), anemia (18%), line sepsis (10%), and hyperkalemia (7%). We observed complications in dialysis access and during dialysis sessions. Line sepsis (8%) and clotted access issues (8%) were the most common problems in dialysis access. In the 4 months of our study, the number of dialysis weeks missed after the war was 1 (range 0-2), and the number of sessions missed was 2 (range 0-4), as illustrated in Table 2.

The dialysis patient compliance data demonstrate profound disruptions in continuity of care and access to essential treatments for hemodialysis patients during and after the war. All statistically significant findings represent within-participant changes across the three time points (before, during, and after the war), as assessed using Cochran's Q test. Regular medication adherence declined significantly from 88 (87.1%) before the conflict to 62 (61.4%) during the war, before partially improving to 82 (81.2%) in the current period ($p<0.001$). Reliance on health-insurance–covered medications decreased markedly, falling from 52 (51.5%) pre-war to 5 (4.9%) during the war and remaining critically low at 7 (6.9%) in the current period ($p<0.0001$). Consequently, partial out-of-pocket payment for medications surged from 42 (41.6%) pre-war to 93 (92.1%) during the war and persisted at 89 (88.1%) in the current period ($p<0.0001$). Access to medications supplied through dialysis centers or non-governmental organizations did not change significantly across time points ($p>0.05$). Unavailability or unaffordability of medications increased from 0 (0.0%) before the war to 3 (2.9%) during the war but did not reach statistical significance ($p=0.246$). Continuity of medical oversight deteriorated sharply, with regular nephrologist follow-up decreasing from 87 (86.1%) before the war to 40 (39.6%) during the war, before recovering to 88 (87.1%) in the current period ($p<0.0001$). Similarly, routine blood testing declined from 90 (89.1%) pre-war to 48 (47.5%) during the war, improving to 75 (74.3%) in the current period ($p<0.0001$). Financial strain intensified substantially, with payment for dialysis increasing from 1 (0.9%) before the war to 43 (42.6%) during the war and reaching 100 (100.0%) in the current period ($p<0.0001$). The use of erythropoietin, a critical therapy for anemia management, declined dramatically from 98 (97.1%) pre-war to 39 (38.6%) during the war, with only partial recovery to 85 (84.2%) in the current period ($p<0.0001$) (Table 3). Overall, these findings reflect a severe wartime health-system collapse, characterized by reduced access to monitoring, specialist care, and essential therapies for hemodialysis patients.

Causes of missing follow ups

Financial and availability issues were key barriers, with 51 (50.5%) reporting financial difficulties alone. Barriers to consistent follow-up with a nephrologist included the unavailability of specialists 47 (74.6%), financial barriers 4 (6.3%), and safety concerns 3 (4.8%), as illustrated in Table 4.

Symptom burden

The study revealed a marked deterioration in the clinical and psychological status of hemodialysis patients during the war, with significant increases in symptoms such as nausea, fatigue, edema, depression, and anxiety as well as muscle cramps and chest pain. Other symptoms, such as seizures and itching, remained stable, indicating disease-specific resilience despite external stressors (Table 5).

Table 1. Demographic characteristics of the study participants (n=101)

Characteristic	n (%)
Age (years)	
<60	91 (90.1)
≥60	10 (9.9)
Gender	
Female	49 (48.5)
Male	52 (51.5)
Causes of ESRD	
Hypertension	50 (49.5)
Diabetes	12 (11.9)
Glomerulonephritis	9 (8.9)
Renal stones	9 (8.9)
ADPKD	9 (8.9)
Congenital kidney	7 (6.9)
Other*	5 (4.9)

Note :*Other includes unknown, recurrent UTI, AKI, severe malaria, hemorrhage, analgesia, gold mining, snake bite, SLE, schistosomiasis, reflux uropathy; ESRD: end stage renal disease; ADPKD: autosomal dominant polycystic kidney disease

Table 2. Distribution of hemodialysis treatment disruptions (n=101)

Variables		n (%)
Duration since starting dialysis (year)	≤ 1	16 (15.8)
	1-5	37 (36.7)
	6-10	31 (30.7)
	11-15	15 (14.9)
	> 15	2 (1.9)
Access of dialysis	AVF	79 (78.2)
	Permcath	22 (21.8)
Symptoms	Hypoglycemia	22 (21.8)
	Hypotension	20 (19.8)
	Convulsions	8 (7.9)
	Headache	7 (6.9)
	Vomiting	6 (5.9)
	Muscle cramps (too much removal of fluid)	6 (5.9)
	Itching / Allergy	6 (5.9)
	Hypertension	5 (4.9)
	Rigors	2 (1.9)
	Palpitation	1 (0.9)
	Fever	1 (0.9)
	Diarrhea	1 (0.9)
	Chest pain	1 (0.9)
	Abdominal pain	1 (0.9)
Complications	Line sepsis	8 (7.9)
	Clotted access problem	8 (7.9)
	A/V fistula infection	7 (6.9)
	Malfunction of line	5 (4.9)
Missed dialysis sessions after the war		
Number of dialysis weeks missed after the war		1 (33.3)
Number of sessions missed		2 (66.7)
Reasons for missed sessions		
Financial difficulties		43 (42.6)
Availability / access issues		34 (33.7)
Other reasons		24 (23.7)

Note : AVF : arteriovenous fistula; Permcath : tunneled catheter

Table 3. Dialysis patient compliances between before, during, and after the war

Variable	Before War (Yes/No)	During War (Yes/No)	Current (Yes/No)	p-value
Taking medications regularly	88 / 13	62 / 39	82 / 19	0.00044
Health insurance medications	52 / 49	5 / 96	7 / 94	<0.0001
Partial payment medications	42 / 59	93 / 8	89 / 12	<0.0001
Dialysis center medications	4 / 97	0 / 101	1 / 100	0.121
NGO medications	1 / 100	0 / 101	0 / 101	1.000
Unavailable / Unaffordable	0 / 101	3 / 98	4 / 97	0.246
Regular nephrologist follow-up	87 / 14	40 / 61	88 / 13	<0.0001
Regular blood tests	90 / 11	48 / 53	75 / 26	<0.0001
Paying for dialysis	1 / 100	43 / 58	100 / 1	<0.0001
Taking erythropoietin	98 / 3	39 / 62	85 / 16	<0.0001

Note : p-values were derived from Cochran's Q test for paired binary data

Table 4. Causes of missing follow-ups

Causes of missing follow-ups	Type of issue	n (%)
Causes of lack of routine laboratory monitoring	Financial issues	31 (56.4)
	Unavailability	12 (21.7)
	Unavailability and financial issues	4 (7.3)
	Safety issues	4 (7.3)
	Poor follow up	4 (7.3)
Causes of not taking medications regularly	Financial issues	20 (43.5)
	Unavailability and financial issues	12 (26.1)
	Unavailability	9 (19.6)
	Compliance issues	5 (10.8)
Causes of no follow up by a nephrologist	Unavailable specialist after war	47 (74.6)
	Poor compliance	9 (14.3)
	Financial issues	4 (6.3)
	Safety issues	3 (4.8)

Table 5. Symptom burden over time among displaced hemodialysis patients

	Before War (Burden)				During War (Burden)				Current War (Burden)				p-value
Symptom	None at all	Moderate	Extreme	Total	None at all	Moderate	Extreme	Total	None at all	Moderate	Extreme	Total	
Nausea	6	3	1	10	10	15	8	33	5	5	2	12	<0.001
Vomiting	5	2	1	8	10	12	7	29	4	5	2	11	<0.001
Loss of appetite	5	3	1	9	15	22	13	50	10	14	8	32	<0.001
Weight loss	2	1	1	4	14	22	12	48	10	18	10	38	<0.001
Fatigue	5	3	1	9	15	24	15	54	12	20	14	46	<0.001
Shortness of breath	2	1	1	4	10	15	9	34	4	4	3	11	<0.001
Lower limb swelling	4	2	1	7	12	14	8	34	6	6	3	15	<0.001
Chest pain	1	1	0	2	5	6	4	15	4	5	2	11	0.006
Urge to move legs	1	1	0	2	1	1	1	3	1	1	1	3	0.901
Seizure	1	1	1	3	2	3	2	7	2	2	1	5	0.503
Muscle cramps	1	1	1	3	4	5	4	13	3	4	4	11	0.036
Itching	6	5	3	14	6	7	4	17	6	5	3	14	0.813
Depression symptoms	3	2	1	6	8	11	8	27	7	9	7	23	<0.001
Sleeping problems	1	0	0	1	10	12	11	33	5	7	5	17	<0.001
Anxiety	1	1	0	2	10	13	10	33	6	7	6	19	<0.001

The study demonstrated a profound deterioration in patients' clinical and psychological status during the war. Most symptoms, including nausea, vomiting, loss of appetite, weight loss, fatigue, shortness of breath, lower-limb swelling, depression, anxiety, and sleep disturbances, increased sharply during the conflict, with all showing statistically significant differences across the three time points (before, during, and after the war) (Cochran's Q test, $p<0.001$). These changes indicate severe disruptions in dialysis adequacy, nutrition, fluid balance, and emotional stability. Muscle cramps ($p=0.036$) and chest pain ($p=0.006$) also showed significant variation over time, reflecting compromised metabolic control and cardiovascular stress. In contrast, seizures ($p=0.503$) and itching ($p=0.813$) did not show significant differences across the three time points, suggesting relative stability of these symptoms despite external hardships. Although symptom frequencies declined in the current period, they remained higher than before the war, indicating incomplete recovery. Overall, these

findings highlight substantial and persistent physical and psychosocial burdens among displaced hemodialysis patients, emphasizing the need for targeted rehabilitation, consistent dialysis access, and integrated mental-health support

Thematic analysis of patient feedback

Table 6 presents a thematic analysis of the patient feedback, sorted by the frequency of occurrence. This provides insights into the complex challenges faced by dialysis, which requires multi-faceted solutions to ensure the patients' access to essential healthcare.

The study reflected the profound multifactorial challenges faced by dialysis patients in conflict-affected regions (Table 6). Access and availability emerge as the most critical concern in 48 cases (47.5%), highlighting systemic disruptions such as center closures, overcrowding, and insecurity, which directly threaten continuity of care. Financial burden (37.6%) exacerbates inequities, as patients struggle to cover costs of treatment and transport amid insufficient government support. The impact of war (34.6%) stresses the vulnerability of healthcare infrastructure, while shortages of skilled health workers (22.7%) compromise care quality. Displacement (18.7%) and transportation issues (17.8%) further impede consistent treatment, reflecting how conflict-driven instability magnifies both logistical and socioeconomic barriers to life-sustaining dialysis.

DISCUSSION

The war in Sudan, which escalated on April 15, 2023, has led to a severe disruption in healthcare services for dialysis patients. The WHO has supported patients through universal healthcare services but critical supply shortages have drastically limited access, with many patients now receiving dialysis only once weekly. War has severely disrupted hemodialysis delivery, as reflected in significant treatment interruptions and rising clinical complications.[16] Our study revealed that most patients had long-term dialysis dependence, with 78% using AV fistulas, but still missed a median of 1 week and 2 sessions after the war began. These interruptions were accompanied by high rates of hypoglycemia, hypotension, convulsions, headaches, vomiting, and muscle cramps—symptoms strongly associated with inadequate or shortened dialysis. Access-related complications, including line sepsis, clotted AV access, and fistula infections further indicated system-wide resource shortages. Evidence showed that even brief dialysis interruptions markedly increase hospitalization and mortality risks.[17,18] Similar findings from other conflict zones demonstrate parallel increases in access infections and physiological instability.

Dialysis frequency dropped significantly during the conflict, with median sessions falling from 2 to 1.5 per week, partially rebounding post-conflict, though session duration also declined. These findings highlighted the profound impact of war on dialysis adequacy, patient safety, and overall health outcomes.[19,20] These findings align with a reported study conducted in Sudan which estimated that the prevalence of dialysis-dependent ESRD patients among refugees is 189 patients per million. In Syria, 54% of participants started dialysis in the host country, and 68% received treatment three times per week, indicating a higher and more consistent frequency of dialysis compared to the 1.5 sessions per week reported in Sudan. About 25% of Syrian patients experienced interruptions in their dialysis regimen due to financial issues.[21] This highlights the fact that while the situation in Syria is dire, Sudanese patients experience even lower access to dialysis. According to the WHO, Yemen had approximately 5,200 dialysis patients in 2018, serviced by only 28 dialysis centers. Although the total requirement was for 700,000 dialysis sessions annually, only 15,000 were provided in 2017, indicating a severe shortfall in care provision.[22]

The observed high rates of vascular access complications in our study (8% line sepsis, 8% clotted access, 7% AV-fistula infection, and 5% line malfunction) highlights the higher proportion of fragile dialysis care that occurs under conflict-induced resource constraints, poor hygiene, and interrupted vascular access care. These access problems, when combined with a median missed dialysis period, magnify the risks of access thrombosis, infection, and access loss, which are known precipitants of morbidity, hospitalization, and reduced dialysis adequacy.[23] Evidence supports the finding that regular surveillance and timely intervention can significantly reduce access thrombosis and preserve patency in arteriovenous fistulas.[24]

In conflict or displacement settings, lack of sterile supplies, limited trained personnel, and delayed interventions increase the probability of access failure, sepsis, hospitalization, and even

death.[25] Conflict and displacement deeply require continuity of care and resource availability for dialysis-dependent patients, such that the absence of aforementioned care and resources will lead to dramatic disruptions in medication adherence, access to essential drugs, regular follow-up, and laboratory monitoring. Such breakdowns in healthcare infrastructure and supply chains increase the risk of underdialysis, vascular-access complications, and preventable morbidity and mortality among chronic kidney disease (CKD) patients. Recent analyses from conflict-affected regions including Sudan, Gaza, and Ukraine, conclude that unreliable dialysis services leave patients without life-saving therapies or medications.[26] Moreover, war-related stressors (insecurity, displacement, overcrowded centers) exacerbate the vulnerability of these patients, making adherence and safe dialysis delivery nearly impossible.[27] The collective evidence stresses an urgent need for humanitarian coordination, uninterrupted supply chains, and protective measures for kidney patients in conflict zones; failure to do so results in predictable deterioration and excess mortality.

Disruptions in follow-up care among dialysis patients during conflicts are largely driven by financial constraints, limited healthcare infrastructure, and safety concerns. Reduced coverage by health insurance and restricted availability of essential medications force patients to rely heavily on patient-borne financial expenditures, thereby creating barriers to consistent treatment. Simultaneously, limited access to nephrology specialists and the closure or displacement of healthcare facilities impede regular clinical monitoring, while insecurity and unsafe travel conditions further restrict attendance at follow-up appointments. Studies from conflict-affected regions, including Sudan, Syria, and Yemen, have similarly documented that financial hardship, inadequate healthcare resources, and security challenges are primary determinants of missed follow-ups, contributing to worsened clinical outcomes and increased dialysis-related complications.[28]

Our study revealed a marked deterioration in both clinical and psychological well-being among dialysis patients during conflicts. Key symptoms such as nausea, vomiting, loss of appetite, weight loss, fatigue, dyspnea, lower-limb swelling, depression, anxiety, and sleep disturbances escalated sharply, reflecting disruptions in dialysis adequacy, nutrition, fluid balance, and emotional stability. Increases in muscle cramps and chest pain further suggest compromised metabolic control and cardiovascular strain, while other symptoms, such as seizures and pruritus, remained relatively stable, indicating that some aspects of disease progression were unaffected by external stressors. Although symptom burden has partially improved post-conflict, many patients continue to experience higher-than-baseline physical and psychosocial challenges. These observations align with studies from conflict-affected settings, which highlight that interruptions in renal replacement therapy and inadequate supportive care contribute to persistent morbidity and psychological distress in hemodialysis populations.[29] Patient feedback highlights the multifactorial challenges faced by dialysis-dependent individuals in conflict-affected regions. Access and availability remain the most critical concerns, as disruptions such as dialysis center closures, overcrowding, and insecurity directly threaten continuity of care. Financial constraints further exacerbate inequities, limiting patients' ability to afford treatment, medications, and transportation in the context of inadequate government support. The fragility of healthcare infrastructure during conflict, compounded by shortages of skilled healthcare personnel, undermines care quality and safety. Displacement and logistical barriers such as transportation difficulties further impede consistent treatment. These findings align with reports from conflict zones, which emphasize that instability, resource scarcity, and structural barriers significantly compromise dialysis delivery and patient outcomes, stressing the urgent need for resilient healthcare systems, uninterrupted dialysis services, and integrated psychosocial support for vulnerable populations.[30]

Our study has the following limitations. Firstly, as there are limited studies conducted in Sudan, we were unable to compare our findings with previous studies that share similar demographic and cultural characteristics. Secondly, we could not obtain or access valuable laboratory data from renal failure patients, such as hemoglobin levels, urea, creatinine, serum calcium, phosphate, and parathyroid hormone, due to logistical challenges. Also, this study was conducted in a single dialysis center.

This study has important clinical and public health implications for the care of hemodialysis patients in conflict and displacement settings. The findings clearly demonstrate that war-related disruption leads to reduced dialysis frequency and

duration, compromised medication access, increased out-of-pocket expenditure, and loss of continuity of specialist care. Clinically, these disruptions translate into a higher burden of preventable complications such as fluid overload, anemia, intradialytic hypotension, hypoglycemia, vascular access infections, and recurrent hospital admissions. The marked deterioration in physical and psychological symptoms further indicates that underdialysis and interrupted supportive care have both short- and long-term consequences on patient survival and quality of life.

For clinicians working in humanitarian or resource-limited settings, the results emphasize the need to prioritize dialysis adequacy, vascular access protection, and uninterrupted access to essential medications such as erythropoietin. Early identification of patients missing sessions, proactive management of anemia and volume overload, and simplified follow-up protocols are crucial to reduce morbidity. At the health-system level, the study highlights the vulnerability of dialysis-dependent patients during crises and underscores the necessity of integrating renal replacement therapy into emergency preparedness and humanitarian response plans. Ensuring secure supply chains for dialysis consumables, medications, and laboratory monitoring should be considered life-saving interventions rather than elective services during armed conflict.

Future research should build on these findings by conducting multicenter and longitudinal studies to better quantify the long-term impact of war-related dialysis disruption on morbidity, mortality, and health-related quality of life. Incorporation of laboratory parameters, such as hemoglobin, urea, creatinine, calcium, phosphate, and markers of dialysis adequacy, would allow more objective assessment of clinical outcomes. Comparative studies across different conflict-affected regions could help identify context-specific and transferable strategies that improve resilience of dialysis services.

There is also a need to evaluate alternative and adaptive care models, including flexible dialysis scheduling, mobile dialysis units, decentralized services, and the feasibility of peritoneal dialysis in displacement settings. Future interventions should integrate mental health screening and psychosocial support as routine components of dialysis care during humanitarian crises. Finally, policy-oriented research is required to inform national and international stakeholders on sustainable financing mechanisms, insurance coverage restoration, and coordinated humanitarian support to ensure uninterrupted, equitable access to life-sustaining dialysis care for displaced populations.

CONCLUSION

Displaced hemodialysis patients in Sudan face substantial morbidity due to war-related disruptions in care, including reduced dialysis frequency and duration, increased out-of-pocket costs, and limited access to essential medications such as erythropoietin. These disruptions have resulted in increased complications and impaired physical and psychological well-being. While the observed effects are severe, they likely represent only a fraction of the true burden imposed by ongoing conflict. The growing demand and capacity constraints at receiving centers such as Atbara Teaching Hospital underscore the urgent need for sustained humanitarian support, expanded infrastructure, and further research to fully characterize and mitigate the long-term consequences of displacement on this vulnerable population.

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Data Availability Statement

There were no new data generated, data sharing is not applicable

Conflict of Interest

The authors declare that no conflicts exist.

Author Contributions

SMA and SKM were responsible for the conceptualization and design of the study; they also supervised data collection and drafted the initial manuscript. MOE coordinated the overall study, performed data analysis, and critically revised the manuscript. WAK and HOB contributed to study design, clinical data interpretation, and manuscript editing. AMA and OB assisted with data acquisition and statistical analysis. AK and AAO contributed to literature review, data validation, and manuscript preparation. FOE provided senior oversight, contributed to interpretation of results, and performed major critical revisions of the

manuscript. All authors have read and approved the final manuscript.

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Declaration the Use of AI in Scientific Writing

The authors state that AI tools were exclusively utilized for grammar and language verification during the production of this manuscript. No artificial intelligence tools were employed for data analysis, interpretation, or the derivation of scientific conclusions.

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