

Systematic Review

Cite this article: Yang F, Zhu L and Li S (2024). Treatment-related Problems and Countermeasures for Patients Undergoing Maintenance Hemodialysis Following Tropical Cyclones: A Scoping Review. *Disaster Medicine and Public Health Preparedness*, **18**, e117, 1–9 <https://doi.org/10.1017/dmp.2024.70>

Received: 26 June 2023

Revised: 20 February 2024

Accepted: 04 March 2024

Keywords:

cyclonic storms; kidney failure; hemodialysis

Corresponding author:

Linfang Zhu;

Email: 1049865005@qq.com

Treatment-related Problems and Countermeasures for Patients Undergoing Maintenance Hemodialysis Following Tropical Cyclones: A Scoping Review

Fengxue Yang¹ , Linfang Zhu²  and Sijian Li³

¹Sichuan Nursing Vocational College, Chengdu, Sichuan, China; ²Department of Nephrology, Kidney Research Institute, West China Hospital of Sichuan University, Chengdu, Sichuan, China and ³School of Nursing, The Hong Kong Polytechnic University, Kowloon, Hum Hung, China

Abstract

Background: Patients undergoing maintenance hemodialysis face heightened vulnerability during disasters like tropical cyclones, yet there is sparse research on their treatment-related challenges and countermeasures. This scoping review aims to highlight the issues maintenance hemodialysis patients encounter following tropical cyclones.

Methods: A systematic scoping review of 19 articles from 2000 to 2023 was conducted, evaluating eligibility against predefined criteria.

Results: Hemodialysis patients encounter substantial challenges during and after tropical cyclones in the United States, Puerto Rico, Australia, and Taiwan. Thematic analysis identified 3 themes related to “challenges” (Hemodialysis health-related challenges, socially relevant challenges, and challenges of management inefficiencies). “Recommendations” comprised 4 themes and 4 phases across the “mitigation phase” (fortifying healthcare infrastructure and mobilizing community-focused risk mitigation initiatives), “preparedness” (emergency plan development, training, and patient education), “response” (activation of emergency plans and providing emergency healthcare services), and “recovery” (intersectoral collaboration for recovery and rebuilding).

Conclusion: This scoping review underscores challenges confronted by patients undergoing maintenance hemodialysis post-tropical cyclones, highlighting the urgent need for targeted strategies to ensure the continuity of dialysis care during and after such disasters.

Context and Rationale

Tropical cyclones are severe weather phenomena that endanger certain regions worldwide each year. These weather events are called by different names depending on the location, such as hurricanes, typhoons, and cyclones, as classified by the World Meteorological Organization (WMO).¹ Over the past 50 years, tropical cyclones have caused numerous disasters, resulting in significant human and economic losses.² With climate change, the frequency and intensity of these extreme weather events are expected to increase.

Individuals with chronic comorbidities, such as respiratory disease, hypertension, and kidney disease, are at a higher risk for adverse health outcomes during and after tropical cyclones. This is because tropical cyclones can impact health through various behavioral, physical, and physiological pathways.³ For example, power outages can disrupt the use of respiratory equipment, leading to respiratory complications.⁴ Furthermore, patients with respiratory illness may experience worsening symptoms due to the physical stress of cyclones, including high winds and exposure to harsh weather conditions.⁵ For patients with kidney disease, damage to, or disruption of dialysis equipment due to lack of healthcare resources can interrupt dialysis treatments. Patients with high blood pressure may experience uncontrolled blood pressure due to a lack of medication. The psychological burden of disasters may also disrupt blood pressure control, a risk factor for patients with kidney diseases, including those receiving dialysis treatment.⁶ Moreover, high blood pressure, also known as hypertension can be significantly impacted by the psychological stress,⁷ and anxiety that result from natural hazards like tropical cyclones. This can potentially increase the risk of cardiovascular events and other health complications. The interaction between behavioral, physical, and psychological stressors highlights the increased vulnerability of individuals with chronic conditions during and after tropical cyclones.

The global all-age prevalence of chronic kidney disease (CKD) has risen by 29.3% since 1990, and kidney disease has a significant impact on global health, as it is a direct cause of morbidity and mortality worldwide.⁸ Tropical cyclones occur frequently, affect wide areas, and have significant impacts on patients with kidney disease. Observational studies have identified an increase in the

initiation of dialysis following disasters, particularly due to hypertensive nephropathy.⁹ Damage to infrastructure, such as electric utilities and backup generators, can lead to interruptions in treatment for patients requiring regular hemodialysis. The number of end-stage renal disease (ESRD) patients receiving maintenance hemodialysis (MHD) treatment is increasing annually. Tropical cyclones put MHD patients at risk, causing fluid overload, heart failure, and electrolyte disturbances due to missed scheduled dialysis sessions.¹⁰ Patients who miss more than 3 sessions are at higher risk of hospitalization and developing posttraumatic stress disorder (PTSD).¹¹

Previous studies have revealed the unique vulnerabilities of hemodialysis patients during disasters, including tropical cyclones.^{4,12} Tropical cyclones often cause power outages and infrastructure damage, which can severely disrupt dialysis centers, posing major challenges for patients reliant on regular dialysis treatments.¹³ Access to essential care can be compromised during and after cyclones, resulting in missed or delayed dialysis sessions and subsequent health complications such as electrolyte imbalances, fluid overload, and toxin build-up.¹¹ Furthermore, the psychological stress of surviving a tropical cyclone can exacerbate patients' existing health conditions, like hypertension, which is common among hemodialysis patients.¹³ These studies highlight the urgent need for disaster preparedness plans tailored to these patients' needs, including resilient infrastructure, alternative power sources, and effective emergency notification strategies to ensure their well-being in cyclone-prone regions.

However, few studies have examined treatment-related problems after tropical cyclones or identified the primary reasons behind dialysis barriers for patients undergoing hemodialysis. Building on the findings of retrospective studies, this scoping review aims to fill these knowledge gaps by systematically mapping the research in this field.

The review will focus on the failure of patients to participate in hemodialysis regularly according to the prescribed regimen and assess the primary causes of treatment problems. This review will focus on the management of MHD patients during tropical cyclones, a critical subset of extreme weather events that have distinctive characteristics and pose specific challenges.

Purpose of the Current Review

Therefore, this study is a scoping review aiming to identify and summarize the problems and causes related to the treatment of patients with MHD in the aftermath of tropical cyclones, and provide actionable recommendations for contingency planning before, during, and after disasters. The rationale for employing a scoping review approach includes: (1) It can depict key concepts and synthesize available evidence when an area is complex or unexamined; (2) It summarizes findings for policymakers, patients, and healthcare workers who may lack time or resources to conduct reviews themselves; and (3) It can address management approaches related to patients on MHD during and after tropical cyclones and point to areas for further research.¹⁴

Methods

Scoping Review Design

The study followed the methodology framework proposed by Arksey and O'Malley,¹⁵ which included 5 steps: (1) identifying the

research questions, (2) identifying relevant studies, (3) study selection, (4) data extraction, and (5) data analysis and synthesis. The report follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) scoping review checklist extension (see [Addendum 1](#)).

Research Questions

In line with the objectives of this study and the observed impacts on MHD patients during or after tropical cyclones, we formulated our research questions to address the specific challenges and solutions for MHD patients during cyclones: (1) What are the treatment-related problems and causes faced by maintenance hemodialysis patients during or after tropical cyclones? (2) What is the nature of the recommendations made to eliminate/ mitigate the challenges?

Search Strategy

The search strategy sought to identify peer-reviewed studies published in English from January 1, 2000, to March 31, 2023. We searched 5 databases, including PubMed, Embase, and CINAHL Complete (EBSCO), as well as Web of Science, and Scopus. The search terms included hemodialysis, dialysis, renal replacement therapy, and ESRD, as well as tropical cyclones, hurricanes, typhoons, and cyclones. Other terms included storms, tornadoes, treatment, and therapy, as well as regimen. We used Boolean operators such as "AND" and "OR" to combine these keywords (See [Addendum 2](#) for the search strategy).

Study Selection

Eligibility criteria

The inclusion criteria for including relevant studies to be reviewed were as follows: studies relevant to MHD during and after tropical cyclones were included in the review process. However, literature reviews, perspectives, conference abstracts, and gray literature were not included in this review.

Studies with the following characteristics were excluded: (1) Studies on tropical cyclones that did not analyze impacts on MHD in depth, and (2) Research on disasters during pandemics, which can cause widespread health problems and pose problems in the delivery of health care services.¹⁶ Our focus is specifically on the direct effects of cyclones on MHD treatment facilities and patient care. Exclusions were applied consistently up to the final stage of data extraction, as typical in scoping studies.

Data Extraction

Data will be extracted independently by 2 researchers (FXY and LFZ), starting with an Excel spreadsheet to ensure that the table contains all relevant data about the study objectives. Data extraction, the title and abstract review, and full-text review will be split into 2 phases. Two researchers (FXY and LFZ) conducted the pilot study using 6 randomly selected eligible articles. Revisions were made by including additional unforeseen data generated from articles considered important to promote the review objectives. Disagreements will be resolved through discussion and, if necessary, consultation with an additional reviewer (SJL). Authors of individual studies will be contacted for more information if necessary (see [Addendum 3](#)).

Data Analysis and Synthesis

In this scoping review, we applied thematic analysis to dissect qualitative data from selected studies, taking inspiration from methodologies utilized in analogous disaster research.^{17–20} Themes emerged organically from the data on the impact of tropical cyclones on MHD patients. This approach ensured that each theme accurately reflected the core content of the studies. Our rigorous iterative review and refinement of the themes guaranteed a thorough understanding of the presented narratives. Our methodological stance facilitated a detailed examination of the specific challenges hemodialysis patients face during tropical cyclones, as well as the strategies devised to address them. Consequently, we pinpointed patterns and themes that accurately reflect the experiences and challenges of MHD in the context of tropical cyclones.

Results

Selection of Publications

The search produced 867 initial matches. After removing 325 duplicates, a total of 417 records that did not meet the inclusion criteria based on title and abstract screening were excluded. Of the remaining 125 full-text studies, a further 105 studies were excluded after full-text screening, leaving 19 studies for analysis (see Figure 1).

Publication and Study Characteristics

A total of 19 studies met the inclusion criteria for this scoping review, all of which analyzed the effects of tropical cyclones, including hurricanes and typhoons, on the treatment of hemodialysis patients. These studies spanned a range of geographic locations,

such as the United States, Australia, and Puerto Rico, as well as Taiwan (see Table 1).

Collating, Summarizing, and Reporting Results

We reviewed and summarized the 19 studies based on the location where the tropical cyclone occurred, which included the United States, Puerto Rico, and Australia, as well as Taiwan. Table 1 summarizes the characteristics of tropical cyclones highlighted in the studies reviewed, their impact on dialysis treatment, the positive responses, and effective strategies identified in each disaster. This approach provides insights into how the selected studies addressed the cyclone impacts on dialysis care. It helps readers better understand the results and discussions presented in this study.

The studies were conducted in various regions, such as the United States, Australia, and Taiwan (see Table 1). They examined factors such as lack of access, insufficient electricity, inadequate disaster preparedness, and the consequences of hemodialysis interruptions, including delays, interruptions, and shorter treatment times. Patient-related, hospital-related, and community-related factors were identified as primary reasons for delays, and missed treatments, with hospital and community preparedness influencing dialysis disruptions, individual patient circumstances, and medical resource constraints affecting delays and missed treatments. Additionally, infrastructure and transportation played roles in both scenarios, with shorter treatment times linked to accommodating surges in patients' needs.

Identification and Synthesis of Problems and Positive Aspects

Considering our qualitative analytical approach, thematic analysis was conducted to identify and synthesize the prominent issues and

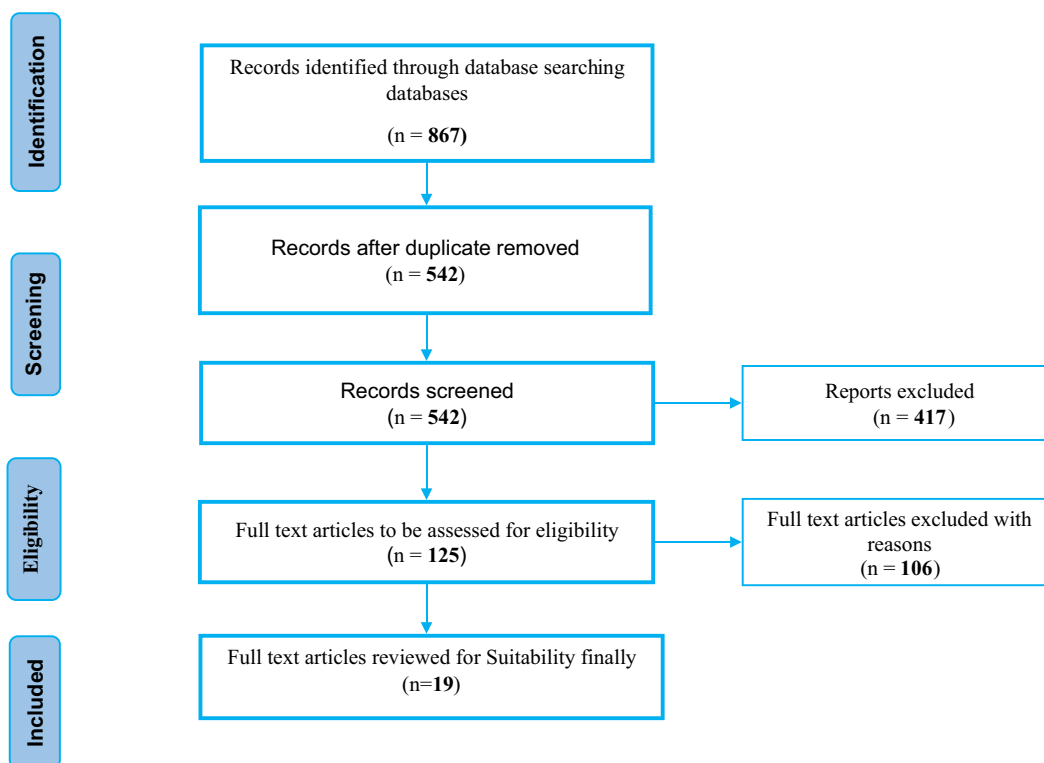


Figure 1. Flowchart of the review process for eligibility. Source: Review selection process and results based on the PRISMA guidelines.

Table 1. Summary of study characteristics

Author, Year	Country	ID and strength	Problem	Positive aspects
Mellgard G, 2019 ²⁶	Puerto Rico	Hurricane Maria (Category 5)	Lack of access to medication and healthcare services, inability to monitor blood pressure and blood sugar levels.	Prioritize needs of vulnerable populations, ensure access to medication and medical care, train healthcare providers to adapt and provide care in unconventional settings.
Kaiser R, 2021 ²⁷	USA	Hurricane Harvey (Category 4)	Power outages, damage to healthcare infrastructure, transportation disruptions, and lack of preparedness among hemodialysis clinics.	Efforts of healthcare providers, emergency responders, and community-based initiatives that provided care, and support, as well as shelter, food, and transportation to ESRD patients.
Kleinpeter MA, 2008 ²⁸	USA	Hurricanes Gustav (Category 4) and Ike (Category 2)	Inadequate knowledge of emergency procedures, lack of communication with healthcare providers, insufficient backup plans for transportation, and power outages.	Efforts of healthcare providers, emergency responders, and community-based initiatives that provided care, and support, as well as shelter, food, and transportation to dialysis patients.
Bonilla-Félix M, 2019 ²⁹	Puerto Rico	Hurricane Maria (Category 5)	Lack of preparedness, inadequate communication, insufficient backup plans for power outages, and transportation disruptions.	Efforts of healthcare providers, emergency responders, and community-based initiatives that provided care, and support, as well as shelter, food, and transportation to nephrology patients.
Kleinpeter MA, 2006 ³⁰	USA	Hurricanes Katrina (Category 3) and Rita (Category 3)	Disruption of dialysis services, inadequate disaster planning, transportation issues, and lack of access to medical supplies and care, as well as communication difficulties.	Collaboration among healthcare providers, emergency responders, and volunteers; resilience and resourcefulness of healthcare providers; relocation of patients to safe facilities.
McArdle J, 2011 ³¹	Australia	Cyclone Yasi (Category 5)	Lack of preparedness, inadequate communication, insufficient backup plans for power outages, and transportation disruptions.	Acknowledges the efforts of healthcare providers and emergency responders who provided care and support to dialysis patients during Cyclone Yasi. Importance of community-based initiatives that provided shelter, food, and transportation to dialysis patients.
Abir M, 2013 ³²	USA	Hurricane Sandy (Category 3)	Disruption of dialysis services, inadequate backup power systems, lack of access to medical supplies, and care, as well as communication difficulties, and transportation issues.	Collaboration among healthcare providers, emergency responders, and volunteers; resilience and resourcefulness of healthcare providers; relocation of patients to safe facilities.
Anderson AH, 2009 ³³	USA	Hurricane Katrina (Category 5)	Missed dialysis sessions, increased hospitalization rates, disrupted access to healthcare services, and patient displacement.	Collaboration among healthcare providers, dialysis centers, and emergency responders; temporary provision of dialysis services in alternative locations.
Chang CM, 2021 ³⁴	Taiwan	Typhoon Morakot (Category 2)	Disrupted access to healthcare services, potential decline in quality of care, and transportation difficulties.	Coordination and collaboration among healthcare providers, dialysis centers, and emergency responders; commitment to maintaining quality care.
Dossabhoj NR, 2015 ³⁵	USA	Hurricanes Katrina (Category 5) and Rita (Category 3)	Increased demand for dialysis services, strain on healthcare resources, and patient displacement.	Collaboration and resource sharing among healthcare providers and dialysis centers, as well as provision of care to displaced patients.
Johnson DW, 2012 ³⁶	Queensland	Cyclone Yasi (Category 5)	Disrupted access to healthcare services, transportation difficulties, strain on healthcare resources, and risk of waterborne diseases.	Collaboration and resource sharing among healthcare providers and dialysis centers, as well as effective disaster response and management.
Lempert KD, 2013 ³⁷	USA	Hurricane Sandy (Category 3)	Disruptions in dialysis services, increased hospital admissions, delayed dialysis treatments, and complications due to missed treatments.	Collaboration among healthcare providers, resource sharing, and emergency management.
Lin CJ, 2014 ³⁸	USA	Hurricane Sandy (Category 3)	Disruptions in dialysis services, increased emergency department visits, transportation difficulties, and infrastructure damage, as well as strain on healthcare resources.	Collaboration among healthcare providers, resource sharing, and emergency management.
Lukowsky LR, 2019 ³⁹	USA	Superstorm Sandy (Category 3)	Disruptions in dialysis services, transportation difficulties, and limited availability of non-VA dialysis services.	Collaboration among VA and non-VA healthcare providers, resource sharing, and emergency management.

(Continued)

Table 1. (Continued)

Author, Year	Country	ID and strength	Problem	Positive aspects
Murakami N, 2015 ⁴⁰	USA	Hurricane Sandy (Category 3)	Low levels of disaster preparedness, lack of knowledge about emergency planning, inadequate supplies of medication, and necessary items.	Improved awareness of the need for disaster preparedness among patients and healthcare providers.
Avilés Mendoza GJ, 2021 ⁴¹	USA and Puerto Rico	Hurricane Irma (Category 5)	Disruptions in dialysis services, transportation difficulties, lack of adequate facilities, and resources.	Successful evacuation and coordination, as well as continuity of care for evacuated patients.
Rivera–Hernandez M, 2022 ⁴²	Puerto Rico	Hurricane Maria (Category 5)	Increased mortality among kidney failure patients, disruptions in dialysis services, and migration of patients to the continental US.	Awareness of the impact of disasters on vulnerable populations.
Lukowsky LR, 2022 ⁴³	USA	Hurricane Irma (Category 5) and Hurricane Maria (Category 5)	Disruptions in dialysis services, challenges in maintaining continuity of care, and transportation difficulties.	Coordination and collaboration between VA healthcare system and dialysis providers, as well as adaptability of healthcare providers.
Blum MF, 2022 ⁴⁴	USA	Multiple Hurricanes	Increased mortality risk among dialysis patients, disruptions in dialysis services, and challenges in maintaining continuity of care.	Awareness of the increased risk for dialysis patients during hurricanes.

beneficial practices evident from the data.^{21,22} This allowed us to identify and synthesize the primary issues emerging in the wake of each tropical cyclone. The resulting thematic structure, presented in Table 2, was essential in deconstructing the complexity of the myriad problems documented across the literature.

To provide a comprehensive overview of the findings from this scoping review, which aims to address our primary research questions, Table 2 has been structured to go beyond documenting specific difficulties faced by MHD patients during tropical cyclones. The table summarizes a range of challenges and key manifestations identified in the study. This approach facilitates a more holistic understanding of the issues at hand, to enable deeper analysis of the broader implications and potential solutions in the field of disaster medicine and patient care.

Importantly, our analysis shows a strong link between all successful measures and the response phase of comprehensive emergency management (see Figure 2).^{23,24} We have therefore expanded the scope from immediate response strategies to include “effective disaster risk reduction (DRR)” measures.²⁵ This approach ensures comprehensive coverage of strategies applicable to all phases of disaster management, including mitigation, preparedness, and response as well as recovery.

Table 2. The way tropical cyclones may affect people with MHD

Core Challenges	Specific Manifestations
Hemodialysis health-related challenges ^{26–39,41–43}	Delayed hemodialysis treatments
	Treatment interruption
	Shortened hemodialysis time
Socially relevant challenges ^{26–28,30–31,33,35,37–39,41,43}	Healthcare infrastructure disruptions
	Transportation
	Loss of electricity and clean water
Challenges of management inefficiencies ^{29–33,35–38,40–44}	Inadequate disaster preparedness

Unveiling the Impact of Tropical Cyclones on Hemodialysis Treatment

Research question 1

What are the treatment-related problems and causes faced by MHD patients during or after tropical cyclones?

In response to the first research question, selected studies unveiled a spectrum of treatment-related challenges experienced by dialysis patients in the aftermath of tropical cyclones. These challenges included disruptions in dialysis services, limited access to medicines and medical services, transportation difficulties, and inadequate disaster planning, as detailed in Table 1. Notably, factors such as power outages and traffic disruptions contribute to patients frequently missing dialysis sessions. Approximately 50% of the studies indicated a subsequent increase in hospitalizations,^{32–33,35,37–38,42–44} with a small number mentioning patient deaths.^{41–43}

To systematically explore and address the challenges identified, we summarized a series of issues in 3 different underlying themes in the field of dialysis care during tropical cyclones (see Table 2). This comprehensive analysis aims to identify key themes and potential patterns in these issues, highlighting the complex landscape of dialysis patient care in the aftermath of such an event. Our survey of these areas revealed important insights into the state of preparedness and response, highlighting the need for a robust strategy in the face of tropical cyclones.

In our scoping review, thematic analysis was employed for qualitative analysis. This involved systematically coding the collected data to identify recurring themes and patterns. Each theme was thoroughly analyzed to understand its significance in the context of the impact of tropical cyclones on maintenance hemodialysis patients. This qualitative summary provides an in-depth understanding of the challenges and strategies identified in the literature.

After thoroughly examining and synthesizing the research, the team focused on 3 overarching themes that represent the challenges faced by dialysis patients after tropical cyclones. Table 2 provides a detailed description of these themes: the fragile state of preparedness identified in the research, which is summarized into 3 agreed-upon themes; hemodialysis health-related challenges; socially relevant challenges; and challenges of management inefficiencies.

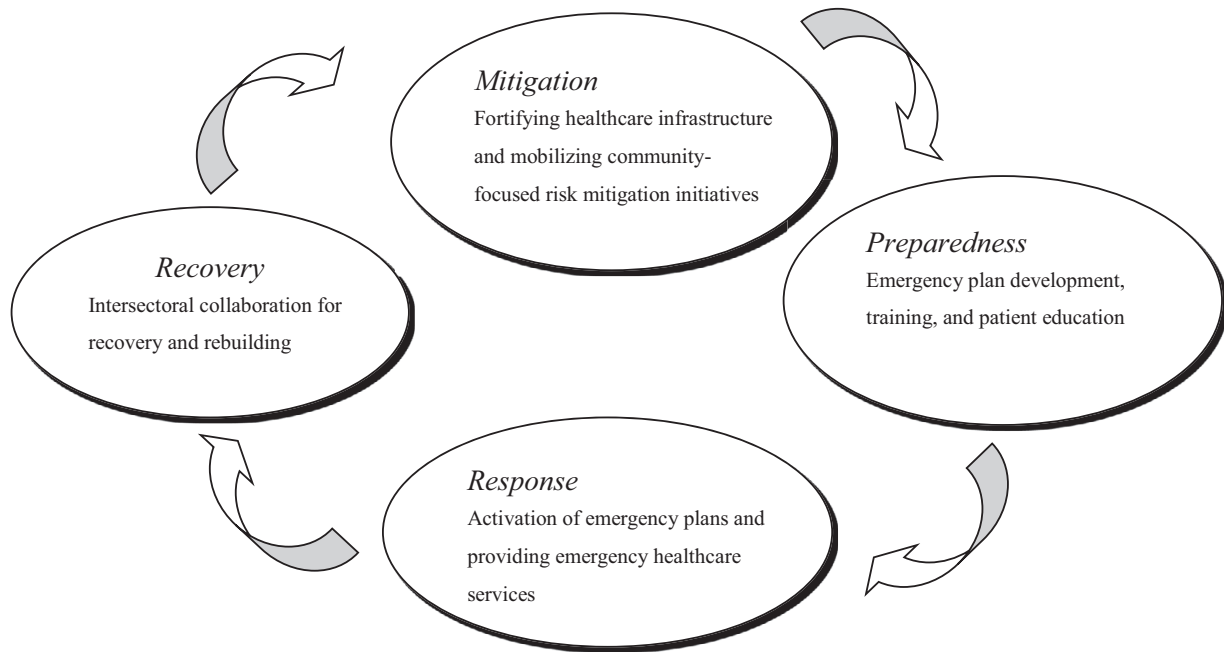


Figure 2. The Four Phases of Emergency Management.

Research question 2

What is the nature of the recommendations made to eliminate/mitigate the challenges?

Table 3 addresses our second research question on the recommendations for mitigating the challenges faced by patients with MHD during tropical cyclones. The recommendations are informed by the effective strategies and positive aspects observed in Table 1 (see Table 3). In this context, the recommendations specifically targeted MHD patients, addressing the unique challenges and needs they face during tropical cyclones. The community was engaged in preparing for cyclones, implementing safeguards, fostering cross-sectoral collaboration, and coordinating with hospitals. The roles of hospitals and communities were explored, focusing on preparations before cyclones, and ensuring medical treatment for patients during such events.

Additionally, the researchers categorized the recommendations into 4 target phases based on relevant measures during and before tropical cyclones. These effective Disaster Risk Reduction (DRR) practices include fortifying healthcare infrastructure, emergency plan development, activation of emergency healthcare services, and intersectoral collaboration for rebuilding.

Furthermore, 16 actionable recommendations were identified and distributed across 4 target disaster phases aligned with comprehensive emergency management: the 'mitigation phase,' 'preparedness phase,' 'response phase,' and 'recovery phase' (see Table 3). This framework highlights strategic measures to address the challenges faced by MHD patients, covering the entire spectrum of a tropical cyclone's impact, including the preparatory, and reconstruction phases. This comprehensive approach facilitates a thorough understanding of the unique difficulties encountered before, during, and after tropical cyclones.

Table 3. Disaster risk reduction strategies and related actions

Themes for DRR	Related factors	Categories of Actions Before, During, and After a Disaster	Target Disaster Phase
Fortifying healthcare infrastructure ^{26–29,33–44}	Patient Community Hospital	<ol style="list-style-type: none"> 1. Prioritize needs of vulnerable populations 2. Ensure access to medication and medical care 3. Secure continuity of dialysis services 4. Foster collaborative relationships 5. Encourage patient engagement in safety planning 	Mitigation
Emergency plan development ^{27–37,40,43}	Patient Community Hospital	<ol style="list-style-type: none"> 1. Ensure continuity of dialysis services 2. Encourage adherence to emergency plans 3. Maintain communication with families 	Preparedness
Activation of emergency healthcare services ^{29–31,35–36,42}	Patient Community Hospital	<ol style="list-style-type: none"> 1. Train healthcare providers for unconventional settings 2. Ensure transportation and water supply 3. Address health needs of vulnerable populations 4. Maintain quality of care 5. Provide emergency dialysis services 	Response
Intersectoral collaboration for rebuilding ^{27,32,37–38,40,43}	Patient Community Hospital	<ol style="list-style-type: none"> 1. Restore healthcare services 2. Support long-term patient needs 3. Community rebuilding 	Recovery

Discussions

As far as we know, this is the first scoping review of its kind, offering a comprehensive exploration of post-tropical cyclone care complexities for MHD patients, and the key factors contributing to these challenges. Although the review focuses on data from high-income countries, the central themes and insights extracted from the review have broad applicability across diverse contextual and environmental settings. This review provides critical insights and valuable lessons in this domain, particularly highlighting that the primary causes of treatment-related issues often revolve around healthcare infrastructure and community dynamics.

Of the types of responses that are effective, those adopted by health systems have been more widely explored in studies, and most of these measures are related to local health systems.^{27–29,31–36,38–39,41,43} In this review, we categorized the identified best practices into 2 main groups: 'Effective response strategies' and 'Recommendations for future preparedness.' This classification enhances understanding in 2 key areas. First, it clarifies the successful actions taken during tropical cyclones. Second, it outlines suggested improvements for future disaster readiness for MHD patients. Hence, based on these classifications, countries can adopt the outlined recommendations. This will enable them to initiate new contingency plans and develop interim strategies, ensuring more comprehensive protection for MHD patients.

Effective Response Strategies for MHD Patients During Tropical Cyclones

In our analysis, we concentrated on identifying specific gaps in disaster preparedness and response for MHD patients, as well as highlighting effective strategies and positive practices observed during tropical cyclones. Challenges emerging during and after tropical cyclones are categorized into 3 principal domains: hemodialysis health-related challenges, socially relevant challenges, and challenges of management inefficiencies. Hemodialysis health-related challenges constitute the primary focus of our discussions (89%).^{26–39,41–43} These challenges predominantly manifest as delayed hemodialysis treatment, treatment interruptions, as well as shortened hemodialysis times, and stem from power failures, water cutoffs, transportation disruptions, and breakdowns in medical infrastructure induced by tropical cyclones.

Our findings align with a 2022 US cohort study, underscoring the heightened vulnerability of patients undergoing dialysis to hurricanes, particularly maintenance dialysis patients who face an elevated risk of death within 30 days after hurricane events.⁴² This emphasizes the health risks posed to dialysis patients due to local exposure to tropical cyclones. In prolonged tropical cyclone scenarios, patients may confront additional risks, including missed dialysis sessions, and inadequate treatment, as well as complications leading to hospitalization, infection risks, and challenges accessing medications. This correlation is consistent with observations from Hurricane Katrina, where 44% of affected patients missed at least 1 dialysis session, 17% missed at least 3, and 23% of patients were hospitalized within a month post-hurricane.^{45,46}

In the realm of socially relevant challenges, the primary cause of dialysis disruption for maintenance hemodialysis patients stems from healthcare infrastructure challenges induced by tropical cyclones, as well as disruptions in transportation, and electric power. Studies on the impact of disasters on hemodialysis patients in the Americas, exemplified by Oquendo et al. (2023),⁴⁷ indicate that disasters can result in power shortages, lack of clean water, and

disruptions in traffic. Mass evacuations and environmental disturbances further lead to the closure of dialysis centers, a surge in dialysis patients at these centers, and increased instances of missed dialysis treatments.^{47,48}

As we delve deeper into these challenges, a potential issue surfaces: challenges of management inefficiencies (74%),^{29–33,35–38,40–44} primarily manifested in inadequate disaster. A cross-sectional study emphasizes the need to enhance management efficiency and disaster preparedness to ensure hemodialysis patients are prepared for emergency dialysis.⁴⁹ Similarly, a study in North Carolina highlights that only about 42% of patients receiving dialysis were adequately prepared for emergency dialysis, corroborating our study findings.⁵⁰

Significant Scopes of Efficient Response Measures

Table 3 shows effective strategies for individuals, hospitals, and communities across 4 themes, with the most explored being fortifying healthcare infrastructure and emergency plan development. By developing a comprehensive emergency plan, dialysis facilities can identify alternative facilities and backup power sources in disasters, power outages, or other emergencies. This proactive approach helps maintain continuity of care for hemodialysis patients and reduces the risk of treatment interruption. For example, in 2016, a study by Connealy et al.⁵¹ found that dialysis facilities with contingency plans experienced fewer treatment interruptions during disasters compared to dialysis facilities without contingency plans. Similarly, in 2018, a study by Kim et al.⁵² highlighted the importance of identifying alternative dialysis facilities, and having adequate backup power sources to ensure continuity of care during emergencies. Therefore, a comprehensive emergency plan for dialysis facilities should include identifying potential risks and hazards, developing emergency protocols, and establishing clear communication channels with patients, staff, and emergency responders. In addition, dialysis facilities should conduct regular training sessions and drills to ensure staff are prepared to implement emergency plans when necessary.⁵³

The development of personal disaster plans at the community and individual levels is considered an effective strategy. Studies have shown that hemodialysis patients with personal disaster plans are more likely to experience fewer treatment interruptions and are better able to manage their medical needs during disasters.⁵⁴ Personal disaster plans should be tailored to the specific medical needs of hemodialysis patients and should include necessary emergency supplies, medications, medical equipment, and important documents such as medical records, insurance information, and emergency contact information.^{26,39–42}

Moore et al. also emphasized prioritizing health system responses, highlighting the importance for decision-makers and administrators to focus on the 4 phases of emergency management.⁵⁵

Important Insights from the Recommendations

The included studies underscore the critical importance of emergency preparedness, communication, and collaboration among stakeholders in mitigating the impact of tropical cyclones on hemodialysis patients (78%).^{27–39,41,43} Effective collaboration and partnerships, proven vital in responding to disasters affecting various healthcare domains, are similarly crucial for dialysis facilities. Actively engaging with utilities, local emergency operation centers, hospitals, and transport companies, as well as health departments, is imperative to ensure the appropriate care and treatment for

hemodialysis patients during and after disasters. For instance, studies like Kenney RJ's in 2007,⁵⁶ emphasize the significance of collaborating with local hospitals and emergency responders to guarantee that hemodialysis patients receive optimal care. Similarly, research by Jain et al.⁵⁷ in 2017, underscores the benefits of partnering with transport companies to facilitate the transfer of hemodialysis patients to alternative dialysis facilities during emergencies.

Limitations

This scoping review's primary limitations include its focus on high-income countries and hemodialysis, potentially overlooking diverse treatment contexts and definitions of treatment-related issues. Consequently, it may not fully represent the challenges in low-income settings, where resource constraints significantly impact healthcare system responses to tropical cyclones. Future research should expand to include various kidney disease treatments, like peritoneal dialysis and kidney transplantation, and examine the broader mental health impacts of disasters on MHD patients. Additionally, exploring emergency planning in varied economic contexts is crucial for developing comprehensive disaster preparedness strategies. This scoping review underscores the need for further investigation into these diverse and complex settings.

Recommendations

The findings could help inform further systematic reviews on the impact of tropical cyclones on MHD patients. There is a lack of data and information on MHD in disasters in low-and middle-income countries (LMICs), highlighting the need for enhanced, reliable, and accurate data collection in LMICs. To help inform policy-making and financing for MHD patients in disasters.

Conclusion

This scoping review provides a comprehensive understanding of the treatment-related problems faced by MHD patients during and after tropical cyclones, along with the primary causes of these problems. The review underscores the critical role of water, electricity, healthcare facilities, and dialysis centers in ensuring the provision of dialysis and the critical need for patients to adhere to prescribed hemodialysis sessions. The review also provides emergency planning countermeasures and recommendations to improve the continuity of dialysis treatment for MHD patients before and after a tropical cyclone. The results underline the vital role of medical staff in emergency preparedness and the prompt activation of contingency plans during disasters to tackle treatment-related issues. Despite some limitations, this review makes a valuable contribution to our understanding of the challenges MHD patients face after tropical cyclones. Implementing the recommended countermeasures can significantly mitigate the impact of disasters on patients with kidney disease.

Abbreviations

CKD	Chronic kidney disease
DRR	Disaster Risk Reduction
ESRD	End-stage renal disease
LMICs	Low-and middle-income countries
MHD	Maintenance hemodialysis

PTSD	Posttraumatic stress disorder
WMO	World Meteorological Organization

Supplementary material. The supplementary material for this article can be found at <http://doi.org/10.1017/dmp.2024.70>.

Data availability statement. The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation, to any qualified researcher.

Funding statement. No funding was received for this study.

Competing interest. This manuscript has not been submitted or accepted for publication elsewhere. The paper is not based on previous communication with a society or meeting. All authors have seen and approved the content and have contributed significantly to the work. The authors declare no potential competing interest.

References

1. **World Meteorological Organization.** *Tropical cyclone*. Published 2022. <https://wmo.int/topics/tropical-cyclone>. Accessed February 4, 2024.
2. **US Global Change Research Program.** *Climate science special report: fourth national climate assessment. Executive summary*. Published 2017. <https://www.globalchange.gov/reports/executive-summary-climate-science-special-report-fourth-national-climate-assessment-nca4>. Accessed February 4, 2024.
3. **Lane K, Charles-Guzman K, Wheeler K, et al.** Health effects of coastal storms and flooding in urban areas: a review and vulnerability assessment. *J Environ Public Health*. 2013;**2013**:913064.
4. **Parks RM, Anderson GB, Nethery RC, et al.** Tropical cyclone exposure is associated with increased hospitalization rates in older adults. *Nat Commun*. 2021;**12**(1):1545.
5. **D'Amato G, Cecchi L, D'Amato M, et al.** Climate change and respiratory diseases. *Eur Respir Rev*. 2014;**23**(132):161–169.
6. **Talge NM, Neal C, Glover V; Early Stress, Translational Research and Prevention Science Network: Fetal and Neonatal Experience on Child and Adolescent Mental Health.** Antenatal maternal stress and long-term effects on child neurodevelopment: how and why? *J Child Psychol Psychiatry*. 2007; **48**(3-4):245–261. doi:10.1111/j.1469-7610.2006.01714.x
7. **Oparil S, Acelajado MC, Bakris GL, et al.** Hypertension. *Nat Rev Dis Primers*. 2018;**4**:18014.
8. **Bikbov B, Purcell CA, Levey AS, et al.** Global, regional, and national burden of chronic kidney disease, 1990–2017: a systematic analysis for the global burden of disease study 2017. *Lancet*. 2020;**395**(10225):709–733.
9. **Smith RS, Zucker RJ, Frasso R.** Natural disasters in the Americas, dialysis patients, and implications for emergency planning: a systematic review. *Prev Chronic Dis*. 2020;**17**:E42.
10. **Ghazali DA, Guericolas M, Thys F, et al.** Climate change impacts on disaster and emergency medicine focusing on mitigation disruptive effects: an international perspective. *Int J Environ Res Public Health*. 2018;**15**(7): 1379. doi:10.3390/ijerph15071379
11. **Schrauben SJ, Chen HY, Lin E, et al.** Hospitalizations among adults with chronic kidney disease in the United States: A cohort study. *PLoS Med*. 2020;**17**(12):e1003470.
12. **Chen J, Tam CY, Cheung K, et al.** Changing impacts of tropical cyclones on East and Southeast Asian inland regions in the past and a globally warmed future climate. *Front Earth Sci Chin*. 2021;**9**. doi:10.3389/feart.2021.769005
13. **Waddell SL, Jayaweera DT, Mirsaedi M, et al.** Perspectives on the health effects of hurricanes: a review and challenges. *Int J Environ Res Public Health*. 2021;**18**(5). doi:10.3390/ijerph18052756
14. **Orach CG.** WHO guidance on research methods for health emergency and disaster risk management. Published 2021. <https://apps.who.int/iris/bitstream/handle/10665/345591/9789240032286-eng.pdf>. Accessed February 4, 2024.

15. **Arksey H, O'Malley L.** Scoping studies: towards a methodological framework. *Int J Soc Res Methodol.* 2005;**8**(1):19–32.
16. **Sever MS, Ortiz A, Maggiore U,** et al. Mass disasters and burnout in nephrology personnel: from earthquakes and hurricanes to COVID-19 pandemic. *Clin J Am Soc Nephrol.* 2021;**16**(5):829–837.
17. **Braun V, Clarke V.** Using thematic analysis in psychology. *Qual Res Psychol.* 2006;**3**(2):77–101.
18. **Shapiro LT, Gater DR Jr, Shultz JM.** It is time to put hurricane preparedness on the radar for individuals living with spinal cord injury. *Spinal Cord Ser Cases.* 2020;**6**(1):34.
19. **Williams S, Jiva S, Hanchey A,** et al. tracking hurricane-related deaths in the contiguous United States using media reports from 2012 to 2020. *Disaster Med Public Health Prep.* 2022;**17**:e234.
20. **Dariagan JD, Atando RB, Asis JLB.** Disaster preparedness of local governments in Panay Island, Philippines. *Nat Hazards.* 2021;**105**(2):1923–1944.
21. **Braun V, Clarke V.** Reflecting on reflexive thematic analysis. *Qual Res Sport, Exerc Health.* 2019;**11**(4):589–597.
22. **Vaismoradi M, Turunen H, Bondas T.** Content analysis and thematic analysis: implications for conducting a qualitative descriptive study. *Nurs Health Sci.* 2013;**15**(3):398–405.
23. **Federal Emergency Management Agency,** Emergency Management Institute. *Animals in disaster: awareness and preparedness. Module A.* Federal Emergency Management Agency; 1998.
24. **Restore Your Economy.** *Phases of disaster.* Published 2024. <https://restoreyoureconomy.org/main/phases-of-disaster/>. Accessed February 6, 2024.
25. **Twigg J,** Humanitarian Practice Network. Disaster risk reduction. Published 2011. <https://www.unesco.org/en/disaster-risk-reduction>. Accessed February 6, 2024.
26. **Mellgard G, Abramson D, Okamura C,** et al. Hurricanes and healthcare: a case report on the influences of Hurricane Maria and managed Medicare in treating a Puerto Rican resident. *BMC Health Serv Res.* 2019;**19**(1):818.
27. **Kaiser R, Karaye IM, Olokunlade T,** et al. Hemodialysis clinics in flood zones: a case study of Hurricane Harvey. *Prehosp Disaster Med.* 2021;**36**(2):135–140.
28. **Kleinpeter MA.** Disaster preparedness of dialysis patients for Hurricanes Gustav and Ike 2008. *Adv Perit Dial.* 2009;**25**:62–67.
29. **Bonilla-Félix M, Suárez-Rivera M.** Disaster management in a nephrology service: lessons learned from Hurricane Maria. *Blood Purif.* 2019;**47**(1–3):199–204.
30. **Kleinpeter MA, Norman LD, Krane NK.** Dialysis services in the hurricane-affected areas in 2005: lessons learned. *Am J Med Sci.* 2006;**332**(5):259–263.
31. **McArdle J.** Cyclone Yasi: dialysis mission impossible. *RSAJ.* 2011;**7**(3):76–8.
32. **Abir M, Jan S, Jubelt L,** et al. The impact of a large-scale power outage on hemodialysis center operations. *Prehosp Disaster Med.* 2013;**28**(6):543–546.
33. **Anderson AH, Cohen AJ, Kutner NG,** et al. Missed dialysis sessions and hospitalization in hemodialysis patients after Hurricane Katrina. *Kidney Int.* 2009;**75**(11):1202–1208.
34. **Chang CM, Chao TYS, Huang YT,** et al. Maintaining quality of care among dialysis patients in affected areas after Typhoon Morakot. *Int J Environ Res Public Health.* 2021;**18**(14). doi:10.3390/ijerph18147400
35. **Dossabhoy NR, Qadri M, Beal LM.** Nephrologic impact of Hurricanes Katrina and Rita in areas not directly affected. *J La State Med Soc.* 2015;**167**(6):254–256.
36. **Johnson DW, Hayes B, Gray NA,** et al. Renal services disaster planning: lessons learnt from the 2011 Queensland floods and North Queensland cyclone experiences. *Nephrology.* 2013;**18**(1):41–46.
37. **Lempert KD, Kopp JB.** Hurricane Sandy as a kidney failure disaster. *Am J Kidney Dis.* 2013;**61**(6):865–868.
38. **Lin CJ, Pierce LC, Roblin PM,** et al. Impact of Hurricane Sandy on hospital emergency and dialysis services: a retrospective survey. *Prehosp Disaster Med.* 2014;**29**(4):374–379.
39. **Lukowsky LR, Dobalian A, Goldfarb DS,** et al. Access to care for VA dialysis patients during superstorm sandy. *J Prim Care Community Health.* 2019;**10**:2150132719863599.
40. **Murakami N, Siktel HB, Lucido D,** et al. Disaster preparedness and awareness of patients on hemodialysis after Hurricane Sandy. *Clin J Am Soc Nephrol.* 2015;**10**(8):1389–1396.
41. **Avilés Mendoza GJ, Finne KP, Torre Leon F,** et al. Observations from the emergency management of dialysis patients evacuated from the US Virgin Islands to Puerto Rico following hurricane Irma. *BMC Health Serv Res.* 2021;**21**(1):1239.
42. **Rivera-Hernandez M, Kim D, Nguyen KH,** et al. Changes in migration and mortality among patients with kidney failure in Puerto Rico after Hurricane Maria. *JAMA Health Forum.* 2022;**3**(8):e222534.
43. **Lukowsky LR, Dobalian A, Kalantar-Zadeh K,** et al. Dialysis care for US military veterans in Puerto Rico during the 2017 Atlantic hurricane season. *Disaster Med Public Health Prep.* 2022;**17**:e187.
44. **Blum MF, Feng Y, Anderson GB,** et al. Hurricanes and mortality among patients receiving dialysis. *J Am Soc Nephrol.* 2022;**33**(9):1757–1766.
45. **Kelman J, Finne K, Bogdanov A,** et al. Dialysis care and death following Hurricane Sandy. *Am J Kidney Dis.* 2015;**65**(1):109–115.
46. **Li D, Staneva J, Bidlot JR,** et al. Improving regional model skills during typhoon events: a case study for Super Typhoon Lingling over the North-west Pacific Ocean. *Front Mar Sci.* 2021;**8**.
47. **Oquendo MA, Friend JM, Halberstam B,** et al. Association of comorbid posttraumatic stress disorder and major depression with greater risk for suicidal behavior. *Am J Psychiatry.* 2003;**160**(3):580–582.
48. **Pisano GP, Bohmer RMJ, Edmondson AC.** Organizational differences in rates of learning: evidence from the adoption of minimally invasive cardiac surgery. *Manage Sci.* 2001;**47**(6):752–768.
49. **Kopp JB, Ball LK, Cohen A,** et al. Kidney patient care in disasters: emergency planning for patients and dialysis facilities. *Clin J Am Soc Nephrol.* 2007;**2**(4):825–838.
50. **Foster M, Brice JH, Shofer F,** et al. Personal disaster preparedness of dialysis patients in North Carolina. *Clin J Am Soc Nephrol.* 2011;**6**(10):2478–2484.
51. **Connealy MB, Lew SQ, Alsamman M,** et al. The emergency department care for hemodialysis patient during the COVID-19 pandemic. *Am J Emerg Med.* 2021;**40**:47–54.
52. **Kim DH.** Emergency preparedness and the development of health care coalitions: a dynamic process. *Nurs Clin North Am.* 2016;**51**(4):545–554.
53. **Singh SP, Tuomainen H.** Transition from child to adult mental health services: needs, barriers, experiences, and new models of care. *World Psych.* 2015;**14**(3):358–361.
54. **Nihonyanagi R, Tsukasaki K, Itatani T,** et al. Factors related to preparedness for emergency hemodialysis in the event of a natural disaster. *Medicine.* 2022;**101**(24):e29288.
55. **Moore S, Mawji A, Shiell A,** et al. Public health preparedness: a systems-level approach. *J Epidemiol Commun Health.* 2007;**61**(4):282–286.
56. **Kenney RJ.** Emergency preparedness concepts for dialysis facilities: reawakened after Hurricane Katrina. *Clin J Am Soc Nephrol.* 2007;**2**(4):809–813.
57. **Jain JA, Temming LA, D'Alton ME,** et al. SMFM special report: putting the “M” back in MFM: reducing racial and ethnic disparities in maternal morbidity and mortality: a call to action. *Am J Obstet Gynecol.* 2018;**218**(2):B9–B17.