

## Original Research

**Cite this article:** Lukowsky LR, Dobalian A, Kalantar-Zadeh K, Der-Martirosian C. Dialysis care for US military veterans in Puerto Rico during the 2017 Atlantic hurricane season. *Disaster Med Public Health Prep.* 17(e187), 1–6. doi: <https://doi.org/10.1017/dmp.2022.63>.

### Keywords:

dialysis; disasters; end stage kidney disease; hurricanes; Puerto Rico; veterans

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# Dialysis Care for US Military Veterans in Puerto Rico during the 2017 Atlantic Hurricane Season

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## Abstract

**Objectives:** Patients with end stage kidney disease (ESKD) are at higher risk for increased mortality and morbidity due to disaster-related disruptions to care. We examine effects of Hurricanes Irma and Maria on access to dialysis care for US Department of Veterans Affairs (VA) ESKD patients in Puerto Rico.

**Methods:** A retrospective, longitudinal cohort study was conducted among VA patients with at least 1 dialysis-related encounter between September 6, 2016, and September 5, 2018. The annual number of dialysis encounters, visits to an emergency department (ED), and the number of deaths pre- and post-hurricanes were compared. A random effects logistic regression model for correlated binary outcomes was fitted for predictors of mortality. Chi-square tests were for differences between pre- and post-hurricane visits.

**Results:** The number of ED visits increased in post-hurricane period (1172 [5.7%] to 1195 [6.6%];  $P < 0.001$ ). ESKD-related ED visits increased from 200 (0.9%) to 227 (1.3%) ( $P < 0.05$ ). Increase in mortality was associated with age (OR = 1.66; CI: 1.23–2.17), heart failure (OR = 2.07; CI: 1.26–3.40), chronic pulmonary disease (OR = 3.26; CI: 1.28–8.28), and sepsis (OR = 3.16; CI: 1.89–5.29).

**Conclusions:** There was an increase in dialysis services at the San Juan VA Medical Center post-Irma/Maria, and access to dialysis care at the non-VA clinics was limited. The role of VA dialysis centers in providing care during disasters warrants further investigation.

Continuity of care for dialysis recipients, including end stage kidney disease (ESKD) patients, is critical as these patients are at heightened risk for increased morbidity and mortality if their typically 3-times-a-week hemodialysis treatment is interrupted. Natural disasters such as earthquakes and hurricanes can lead to disruptions in equipment, electricity, water, communication, and transportation.<sup>1–6</sup> The impact of these types of natural disasters on infrastructure, for example, facility closures due to damaged buildings or roads, or disruptions to electricity, water, and communications, would not differ substantially. However, earthquakes can increase the number of patients with acute kidney failure (AKF) due to crush syndrome, which is common among victims trapped under rubble.<sup>5,6</sup> Patients with crush syndrome require dialysis at least temporarily, which would increase the demand for and reduce access to those services for other ESKD patients. For example, in the month after Hurricane Katrina (2005), more than 50% of the dialysis facilities in Louisiana were still closed due to major damage caused by the hurricane.<sup>7</sup> These closures contributed to an increase in renal-related hospitalizations in the hurricane-affected areas.<sup>8,9</sup> Similarly, during Hurricane Sandy (October 29, 2012), 306 dialysis facilities in New York and New Jersey were closed right after the hurricane struck.<sup>2</sup> Major disruptions in dialysis services caused by Sandy led to missed dialysis care during the first week post-Sandy for both US Department of Veterans Affairs (VA) and non-VA patients. Major disruptions in dialysis services might have contributed to an increase in the 30-day mortality rate of 1.83% in Sandy-affected areas compared to 1.6% for the same month in the preceding year.<sup>7,10</sup>

Dialysis-dependent patients due to ESKD require established vascular access so they can receive dialysis treatments.<sup>11</sup> There are 3 types of vascular access: arteriovenous fistula (AVF), arteriovenous graft (AVG), and central venous catheter (CVC). AVF is considered the safest and currently the most commonly used method. However, a placement of AVF requires surgery and requires usually 2 or more months before it can be used for treatment. Therefore, during emergency dialysis initiation, another vascular access method, most likely a CVC, needs to be used before switching to AVF in subsequent months. The vascular access site has to be monitored on a daily basis by the patient and medical personnel to prevent complications such as infections, stenosis, or thrombosis.<sup>11,12</sup> Complications associated with all types of vascular access have been widely reported in the literature, and can arise at the time of access placement as well as during the maintenance period.<sup>13–16</sup> While complications associated with

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vascular access are common among ESKD patients, during and immediately after a disaster, they can become exacerbated due to shortages of clean water, electricity, and transportation, as well as limited access to dialysis facilities.

In Puerto Rico, after Hurricanes Irma and Maria (September 2017), damage to major infrastructure caused delays in medical care throughout most of the island, and resulted in more than \$50 billion dollars in damages.<sup>17–20</sup> The electrical grid suffered significant damage, leaving the majority of the island's population without power until November 2017, although outages continued through May 2018.<sup>18</sup> Even though 48 out of 58 hemodialysis (HD) units opened almost immediately using generators and water tanks following hurricane Maria, Bonilla-Felix et al. (2019)<sup>3</sup> reported that road damage, fallen power lines, and a shortage of fuel were major barriers accessing dialysis facilities. By October 2017, about 1 month after the hurricanes, all but 33 out of the 6000 ESKD patients on the island had at least 1 contact with their dialysis provider.<sup>20</sup> It was also reported that 600 dialysis patients left the island within a year after Maria.<sup>3</sup>

Prior to the hurricanes, the dialysis unit at the San Juan VA Medical Center (SJVAMC) provided regular outpatient dialysis care to veterans with ESKD. Additionally, the SJVAMC dialysis unit provided inpatient dialysis to veterans with ESKD during their hospitalizations, as well as inpatient dialysis to patients with acute kidney failure (AKF). During and after the 2 hurricanes, the dialysis unit at the SJVAMC remained open and continued serving its veteran patient population. Some VA patients with ESKD who were not receiving maintenance hemodialysis at the SJVAMC prior the hurricanes were treated at the SJVAMC dialysis unit after the 2 hurricanes, most likely because they were unable to access their regular non-VA treatment sites.

This study examined how Irma and Maria affected access to dialysis care for VA ESKD patients at both the SJVAMC and non-VA community clinics. The study hypothesis was that SJVAMC experienced an increase in its volume of dialysis care after the hurricanes because of the aforementioned challenges to delivering care at non-VA dialysis clinics in Puerto Rico.

## Methods

### Cohort Description

A retrospective, longitudinal study was conducted using VA administrative and clinical data from the VA Corporate Data Warehouse. The Puerto Rico dialysis cohort of VA users was defined as VA patients who had at least 1 dialysis-related encounter in Puerto Rico or the US Virgin Islands 1 year before and 1 year after the 2017 hurricane season between September 6, 2016, and September 5, 2018. Current Procedural Terminology (CPT) codes 90935–90937, 90945–90947, 90960–90962, 90999, and G0257 were used to identify procedures related to dialysis treatments at the SJVAMC dialysis unit and non-VA dialysis centers. Visits related to vascular access for dialysis using 101 CPT codes associated with the placement of CVC, AVF, or AVG as well as with complications for vascular access were also examined.

### Analysis

This study compared the annual number of dialysis encounters a year before to a year after the hurricanes at the SJVAMC and non-VA facilities. The number of visits to an emergency department (ED) was also examined 1 year before and 1 year after. Chi-square tests were used to analyze the differences between

pre- and post-hurricane visits to the VA facilities. Additionally, the number of visits related to dialysis vascular access (either due to a placement, a change, or for complications associated with it) was assessed.

A random effect logistic regression model<sup>21</sup> for correlated binary outcomes comparing mortality between pre- and post-hurricane periods was fitted, accounting for the fact that some patients used SJVAMC during both periods, and therefore observations for those patients were not independent because they were included in both the before and after groups. The model adjusted for time-dependent covariates, including age as well as comorbidities (eg, hypertension, diabetes, heart failure [HF], chronic pulmonary disease [CPD], and sepsis). Models of this type are commonly used for outcomes that change over time to accurately estimate both subject-specific effect, accounting for multiple data points for the same subject, as well as between subject effects.<sup>22</sup>

All analyses were performed using the SAS 9.4 and SAS Enterprise Guide 7.1 software packages (SAS Institute, Cary, NC). Proc GLIMMIX was used to fit a random effect model. This study was approved by the VA of Greater Los Angeles Healthcare System (VAGLAHS) Institutional Review Board.

## Results

### Patient Characteristics

The study cohort included 330 dialysis patients who received at least 1 hemodialysis treatment in Puerto Rico: 195 received all dialysis services at the SJVAMC, 20 used only non-VA dialysis clinics, and 115 received dialysis care at both VA and non-VA clinics. This study identified 58 ESKD patients who received maintenance hemodialysis exclusively at SJVAMC during the study period (38 received hemodialysis a month before the hurricanes). [Table 1](#) illustrates the demographic characteristics and comorbid diagnoses before and after the hurricanes. With regard to demographic characteristics, 98% were men, 59% were married, 22% were divorced or separated, 10% were never married, 9% were widowed, 81% were age 65 or older (mean age 73; range 38–98), and the average distance from patients' home to SJVAMC was 19 km (12 miles) (see [Table 1](#), column 3). With regard to comorbid diagnoses, 70% had diabetes, 79% had hypertension, 51% had heart failure, 39% had ischemic heart disease, 36% had sepsis, and 37% had at least 1 diagnosis of infection other than sepsis during the study period (see [Table 1](#), Total column). Between September 2017 and January 2018, 3 ESKD, non-VA patients who had evacuated from the Virgin Islands after Hurricane Irma were treated at the SJVAMC. All 3 received inpatient dialysis in Puerto Rico and were included in this study. During the 2-year study period, there were 115 (35%) deaths and 8 (2%) patients who received a kidney transplant. Additionally, 224 (68%) patients had at least 1 outpatient encounter related to a vascular access (see [Table 1](#), Total column).

During the year prior to the 2 hurricanes, 239 patients received dialysis care either at SJVAMC or at community clinics for which their care was paid by VA, compared to 251 patients in the year following the hurricanes (see [Table 1](#), Pre and Post columns). There were 50 (21%) deaths during the pre-hurricane period (September 6, 2016–September 5, 2017), and 65 (26%) during the post-hurricane period (September 6, 2017–September 6, 2018). During the first year, there were 38 patients with AKD. Out of those, 10 progressed to ESKD, and 19 died (15 during the first year). During a second year, there were 45 patients with AKF. Out of those, 8 progressed to ESKD

**Table 1.** VA ESKD patient characteristics in Puerto Rico, pre/post Hurricanes Irma and Maria (N = 330)

Patient demographics	Pre-hurricanes Irma & Maria (N = 239)	Post-hurricanes Irma & Maria (N = 251)	Total (N = 330)
Male	237 (99%)	247 (98%)	326 (98%)
Married	150 (63%)	145 (58%)	194 (59%)
Never married	22 (9%)	26 (10%)	31 (10%)
Divorced/separated	45 (18%)	56 (22%)	74 (22%)
Widowed	21 (9%)	23 (9%)	30 (9%)
Mean age (range)	72 (38–98)	72 (38–97)	72 (37–98)
Age categories			
18–44	1 (0%)	1 (0%)	1 (0%)
45–64	48 (20%)	50 (20%)	63 (19%)
65+	190 (79%)	200 (80%)	266 (81%)
Comorbidities			
Heart failure**	84 (35%)	120 (47%)	171 (51%)
Ischemic heart disease	73 (31%)	81 (32%)	128 (39%)
Hypertension	170 (71%)	174 (69%)	261 (79%)
Chronic pulmonary disease (CPD)*	7 (3%)	19 (8%)	24 (7%)
Anemia	119 (50%)	111 (44%)	195 (59%)
Parathyroid conditions	14 (6%)	6 (2%)	16 (5%)
Diabetes	161 (67%)	161 (64%)	232 (70%)
Cancer	49 (21%)	48 (19%)	92 (28%)
Hepatitis (any type)*	24 (10%)	11 (4%)	33 (10%)
HIV	3 (1%)	4 (1%)	7 (2%)
Sepsis	64 (27%)	63 (25%)	118 (36%)
Other infections	63 (26%)	66 (26%)	122 (37%)
Mental health diagnoses	111 (46%)	117 (47%)	188 (57%)
Opioid addiction	2 (1%)	3 (1%)	4 (1%)
Other characteristics			
Median distance to SJVAMC from home address, in km (range)	20 (0–141)	18 (0–170)	19 (0–170)
Median driving time to SJVAMC from home address, in min (range)	29 (2–178)	25 (2–167)	20 (2–178)
Deaths	50 (21%)	65 (26%)	115 (35%)
Any vascular access encounters <sup>a</sup>	130 (54%)	139 (55%)	224 (68%)
Kidney transplant	3 (1%)	5 (2%)	8 (2%)

Chi-square tests: \* $P < 0.05$ ; \*\* $P < 0.001$ .

<sup>a</sup>Encounters include establishing vascular access at time of dialysis initiation, changing the access, and visits for complications associated with vascular access.

and 16 died during the study period (data not shown). There were no significant differences between patient characteristics during pre- and post-periods except for the number of patients with a heart failure diagnosis at 84 (33%) versus 120 (47%) ( $P < 0.001$ ), CPD at 7 (3%) versus 19 (8%) ( $P < 0.05$ ), and hepatitis at 24 (10%) versus 11 (4%) ( $P < 0.05$ ).

Table 2 provides information regarding patient characteristics based on mortality status during both pre- and post-hurricane periods. Diagnoses for ischemic heart disease (IHD) (14 [28%] vs 29 [45%],  $P < 0.05$ ) and CPD (3 [6%] vs 8 [12%],  $P < 0.05$ ) increased significantly for patients who died after the hurricane compared to patients who died before the hurricanes.

Figure 1 examines changes between pre- and post-hurricane season, indicating a decrease in the total number of VA outpatient visits from 20 685 during the pre-hurricane period to 18 092 after the hurricanes (14% decrease). While the number of dialysis visits decreased from 7263 to 6948, the percent of dialysis visits out of the total number of visits increased from 35% to 38% ( $P < 0.001$ ). There was an increase in both the number of ED visits during the post-hurricane period from 1172 (5.7%) to 1195 (6.6%) ( $P < 0.001$ ), and in ESKD-related ED visits from 200 (0.9%) to 227 (1.3%) ( $P < 0.05$ ).

Table 3 shows age, period (pre- vs post-hurricanes), and comorbidity adjusted mortality odds ratios (ORs). Age (OR = 1.66; CI: 1.23–2.17), comorbid diagnoses such as heart failure (OR = 2.07; CI: 1.26–3.40), CPD (OR = 3.26; CI: 1.28–8.28), and sepsis (OR = 3.16; CI: 1.89–5.29) were associated with higher mortality. Diabetes and hypertension were associated with lower mortality, with ORs 0.41 (0.25–0.66) and 0.28 (0.17–0.48), respectively. Even though there was an 18% increase in mortality during the post-hurricane period, OR = 1.18 (0.72–1.92), it was not statistically significant ( $P = 0.48$ ).

## Discussion

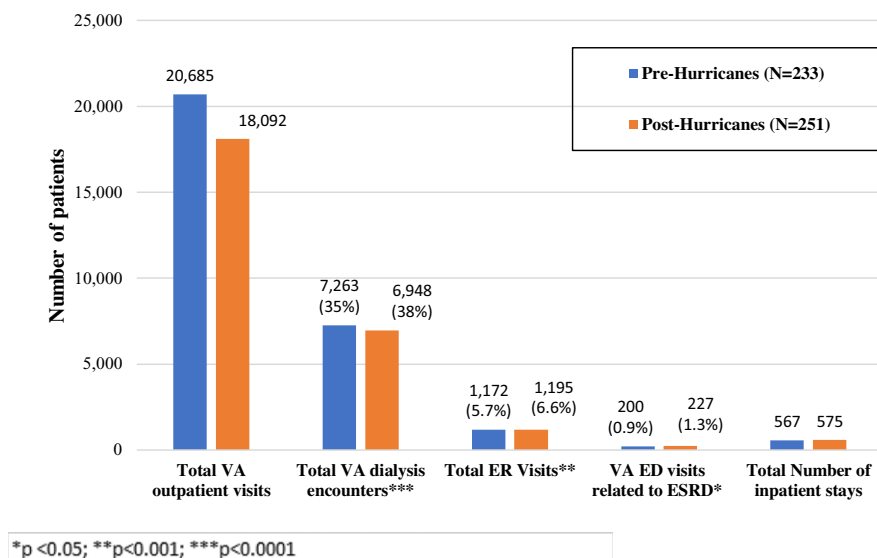
On September 6, 2017, Hurricane Irma made landfall in Puerto Rico and caused significant damage to some parts of the island. Two weeks later, on September 20, 2017, Hurricane Maria, a Category 4 hurricane, caused major destruction and devastation to the entire island.<sup>18</sup> Even though most dialysis facilities on the island were able to reopen within a few days using generators and by making their own clean water,<sup>3,23</sup> many ESKD patients encountered difficulties reaching their regular dialysis care sites

**Table 2.** VA ESKD patient characteristics in Puerto Rico, pre/post Hurricanes Irma and Maria by mortality status (N = 330)

Patient demographics (%)	Pre-hurricanes (N = 233)		Post-hurricanes (N = 251)	
	Died pre-hurricanes N = 50 (100%)	Did not die pre-hurricanes N = 189 (100%)	Died pos-hurricanes N = 65 (100%)	Did not die post-hurricanes N = 186 (100%)
Male	50 (100%)	186 (98%)	65 (100%)	182 (98%)
Married	30 (60%)	120 (63%)	36 (55%)	109 (59%)
Never married	4 (8%)	18 (10%)	8 (12%)	18 (10%)
Divorced/separated	10 (18%)	35 (19%)	14 (21%)	42 (23%)
Widowed	6 (12%)	15 (8%)	7 (11%)	16 (9%)
Mean age (range)	76 (56-98)	71 (37-90)	76 (58-97)	71 (38-91)
Age categories				
18-44	0	1 (0%)	0	1 (0%)
45-64	6 (12%)	42 (22%)	6 (9%)	44 (24%)
65+	44 (89%)	146 (78%)	59 (91%)	141 (76%)
Comorbidities				
Heart failure	23 (46%)	67 (35%)	40 (62%)	80 (43%)
Ischemic heart disease*	14 (28%)	59 (31%)	29 (45%)	52 (28%)
Hypertension	27 (54%)	143 (75%)	35 (53%)	139 (75%)
Chronic pulmonary disease (CPD)*	3 (6%)	4 (2%)	8 (12%)	11 (6%)
Anemia	34 (68%)	85 (45%)	23 (35%)	88 (47%)
Parathyroid conditions	3 (6%)	11 (6%)	2 (3%)	4 (2%)
Diabetes	27 (54%)	134 (71%)	29 (44%)	132 (71%)
Cancer	16 (32%)	33 (17%)	12 (18%)	36 (19%)
Hepatitis (any type)	2 (4%)	22 (12%)	1 (1%)	10 (5%)
HIV	2 (4%)	2 (1%)	2 (1%)	1 (0%)
Sepsis	22 (44%)	42 (21%)	28 (43%)	35 (19%)
Other infections	19 (38%)	44 (23%)	19 (29%)	47 (18%)
Mental health diagnoses	26 (52%)	85 (45%)	35 (54%)	82 (4%)
Opioid addiction	1 (0%)	1 (0%)	1 (0%)	2 (1%)
Other characteristics				
Median distance to SJVAMC from home address, in km (range)	24 (2-113)	19 (0-141)	15 (1-113)	20 (0-170)
Median driving time to SJVAMC from home address, in min (range)	31 (4-122)	29 (2-178)	22 (5-130)	29 (2-167)
Any vascular access encounters <sup>a</sup>	27 (54%)	103 (55%)	39 (60%)	100 (54%)

Chi-square tests: \* $P < 0.05$ ; \*\* $P < 0.001$ .

<sup>a</sup>Encounters include establishing vascular access at time of dialysis initiation, changing the access, and visits for complications associated with vascular access.

**Figure 1.** The number and percent of encounters for VA ESKD patients at SJVAMC, pre/post Hurricanes Irma and Maria.



**Table 3.** Adjusted mortality odds ratios for VA ESKD patients during pre- and post- Hurricanes Irma and Maria (N = 330)

Comorbidity adjusted mortality odds ratios	OR	CI	P
Age (decades)	1.66	1.23-2.17	0.0002
Diabetes (ref = No)	0.41	0.25-0.66	0.0004
Hypertension (ref = No)	0.28	0.17-0.48	< 0.0001
CPD (ref = No)	3.26	1.28-8.28	0.01
HF (ref = No)	2.07	1.26-3.40	0.004
Sepsis (ref = No)	3.16	1.89-5.29	< 0.0001
Year of death (ref = pre-hurricanes)	1.18	0.72-1.92	0.48

because of road damage and transportation issues. Additionally, disruptions to power and telecommunication services made it impossible for many patients to communicate with their dialysis facilities. As in New York after Superstorm Sandy (2012),<sup>24</sup> the absence of medical records and dialysis documentation made the use of alternative dialysis facilities challenging and inefficient, which in turn resulted in delayed or even missed treatments in the first few weeks and even months after Irma and Maria.<sup>23</sup>

The dialysis unit at SJVAMC remained open during and after the hurricanes and continued providing services after the hurricanes. While other dialysis facilities reported about a 15% drop in their patient census through the month of December,<sup>23</sup> the SJVAMC dialysis unit saw an increase in the number of patients during the first month after the hurricanes (September–October 2017), indicating minimal or no interruption of dialysis services.

In total, this study observed an increase from 233 to 251 in the number of patients who used the SJVAMC dialysis clinic in the year following Irma and Maria, although there was a substantial decrease in the general population on the island during that period. An analysis of geocoded tweets by Puerto Rico residents revealed that about 8.3% of the island residents relocated in the months following the hurricanes, and 4% were still displaced by May 2018.<sup>25</sup> These numbers were somewhat higher for ESKD patients as it was reported that about 10% (600 out of 6000) of ESKD patients left Puerto Rico shortly before or after the hurricanes, and a small number of ESKD patients were medically evacuated to the mainland after Maria.<sup>25,26</sup> While the authors did not have information about how many ESKD VA patients relocated from the island post-hurricanes, it is not expected for this number to differ from non-VA dialysis patients. Therefore, the fact that more ESKD VA users sought care at the SJVAMC dialysis unit suggests that VA patients encountered difficulties accessing dialysis care at non-VA, community dialysis clinics after the hurricanes. Additionally, the fact that this study saw very little difference in pre- and post-hurricane attendance among regular VA ESKD patients suggests that the excess number of dialysis patients at SJVAMC after the hurricanes was mostly due to VA ESKD patients who previously received care in community settings before the hurricanes and instead received at least some of their dialysis care at SJVAMC after the hurricanes.

This study observed an increase in the number of ESKD VA patients who either permanently or temporarily switched to receiving care from the VA dialysis unit rather than their regular community clinics, especially during September–October 2017. These observations might indicate that many ESKD patients used SJVAMC on an emergency rather than regular basis, most likely due to limited access to care in community settings. Large integrated health care delivery systems may be better able to handle

post-disaster increased demands, that is, surges, for care, even for extended periods lasting a few months than smaller, standalone facilities. Even though there was an increase in the number of ESKD patients after the hurricanes, the total number of outpatient encounters and the number of dialysis visits decreased in the year following the hurricanes, perhaps because of departures from the island. Nonetheless, the percentage of dialysis visits and ED visits increased significantly following the hurricanes, indicating an overall increase in the acuity level for care. Additionally, this study observed an increase in deaths among ESKD patients from 50 (21%) during the pre-hurricane period compared to 65 (26%) post-hurricanes, although this change was not statistically significant.

This study found that age and various comorbid conditions such as CPD and IHD were significantly associated with mortality. In fact, the study observed an increase from 6% to 12% for CPD and 28% to 45% for IHD. This study also observed an increase in HF diagnoses in patients who died during the post-hurricane period from 46% to 62%, and an increase from 35% to 47% in all patients. Missed or delayed dialysis can lead to volume overload and heart failure. Indeed, the study observed a significant increase in HF diagnoses in the post-hurricane period, which could be related to limited access to dialysis services for the ESKD patients receiving dialysis at non-VA facilities right after the hurricanes. This study found that hypertension and diabetes were associated with lower mortality. The U-shape association between hypertension and mortality where low blood pressure is associated with higher mortality was described previously, and the results are consistent with that finding.<sup>27</sup> Previous studies also showed that obesity is associated with lower mortality in dialysis patients.<sup>28</sup> Since the study did not have data on obesity, the association between diabetes and lower mortality might serve as a predictor of an obesity-mortality association, as there is an established positive link between obesity and diabetes.

This study did not observe any changes in dialysis schedules for the VA dialysis patients. That might be because SJVAMC remained open during the hurricanes. Most likely, ESKD patients receiving dialysis at the VA lived in relatively close proximity to SJVAMC and therefore were less affected by road closures and transportation issues.

This study also observed a significant association between sepsis diagnosis and mortality, which may be related to the problems associated with vascular access as it often leads to infection. More than 50% of the study participants had procedures associated with vascular access. Also, 60% of patients who died after the hurricanes had vascular access-related visits, compared to 54% of those who died before the hurricanes. This might at least partially explain an association between mortality and sepsis diagnosis. While there was no difference in sepsis diagnoses between the pre- and post-hurricane period, more than 40% of patients who died had a sepsis diagnosis compared to about 20% of those who did not.

### Limitations

This study examined access to dialysis care by ESKD veteran patients after a major natural disaster. As the largest integrated health care system in the country, VA can provide resources to assist patients at a time when the local systems get overwhelmed after disasters.

For this study, VA administrative and clinical data that contain comprehensive information about all services VA users received at the VA health care system, as well as services received outside of

the VA, but paid by the VA, were used. Additionally, data on patient demographic characteristics and diagnoses from hospitalizations and outpatient visits at the VA were used.

This study has a few limitations. The authors had access to data from the United States Renal Data System (USRDS)<sup>29</sup> for calendar year 2016 through June 2017 because the availability of Medicare data usually lags in time. Accordingly, the authors were unable to use Medicare information in the analysis and, therefore, were unable to identify Puerto Rico ESKD cohort patients who were enrolled in Medicare after June 2017. Furthermore, the authors were unable to use the USRDS to determine the dates of dialysis initiation and the dialysis modalities at both the time of dialysis initiation and during the post-hurricane period. Additionally, the authors were unable to verify medical care for patients from the study cohort if they left the island or received care that was not paid by the VA.

## Conclusions

This study examined the differences in outpatient encounters, dialysis care, and ED visits among ESKD patients who used VA or non-VA dialysis facilities during the year before and after Hurricanes Irma and Maria in Puerto Rico. There were minimal or no interruptions of services for ESKD patients who were receiving dialysis on a regular basis at SJVAMC during the year following the hurricanes. However, an increase was observed in the number of patients who received dialysis services at SJVAMC during the immediate post-hurricane period, most likely due to limited access to dialysis care at the non-VA clinics. This study shows that SJVAMC served as a safety net for VA ESKD patients after the hurricanes, regardless of whether they were receiving dialysis care at VA or non-VA facilities prior to the hurricanes. These findings have important implications for dialysis services and dialysis resources at VA, since they can assist non-veteran ESKD patients during disasters and pandemics.

**Funding statement.** This material is based upon work supported by the US Department of Veterans Affairs.

**Conflict(s) of interest.** The views expressed in this manuscript are those of the authors and do not necessarily reflect the position or policy of the Department of Veterans Affairs or the US Government.

## References

1. 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.
2. Lempert KD, Kopp JB. Hurricane Sandy as a kidney failure disaster. *Am J Kidney Dis.* 2013;61(6):865.
3. Bonilla-Felix M, Suarez-Rivera M. Disaster management in a nephrology service: lessons learned from Hurricane Maria. *Blood Purif.* 2019;47(1-3):199-204.
4. Lempert KD, Kopp JB. Renal failure patients in disasters. *Disaster Med Public Health Prep.* 2019;13(4):782-790.
5. Fukagawa M. Nephrology in earthquakes: sharing experiences and information. *Clin J Am Soc Nephrol.* 2007;2(4):803-808.
6. Kopp JB, Ball LK, Cohen A, et al. Kidney patient care in disasters: lessons from the hurricanes and earthquake of 2005. *Clin J Am Soc Nephrol.* 2007;2(4):814-824.
7. Kenney RJ. Emergency preparedness concepts for dialysis facilities: reawakened after Hurricane Katrina. *Clin J Am Soc Nephrol.* 2007;2(4):809-813.
8. 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.
9. Howard D, Zhang R, Huang Y, Kutner N. Hospitalization rates among dialysis patients during Hurricane Katrina. *Prehosp Disaster Med.* 2012;27(4):325-329.
10. 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.
11. Santoro D, Benedetto F, Mondello P, et al. Vascular access for hemodialysis: current perspectives. *Int J Nephrol Renovasc Dis.* 2014;7:281-294.
12. Yan Y, Ye D, Yang L, et al. A meta-analysis of the association between diabetic patients and AVF failure in dialysis. *Renal Fail.* 2018;40(1):379-383.
13. Suri RS, Larive B, Sherer S, et al. Risk of vascular access complications with frequent hemodialysis. *J Am Soc Nephrol.* 2013;24(3):498-505.
14. Ellingson KD, Palekar RS, Lucero CA, et al. Vascular access hemorrhages contribute to deaths among hemodialysis patients. *Kidney Int.* 2012;82(6):686-692.
15. Astor BC, Eustace JA, Powe NR, et al. Type of vascular access and survival among incident hemodialysis patients: the Choices for Healthy Outcomes in Caring for ESRD (CHOICE) Study. *J Am Soc Nephrol.* 2005;16(5):1449-1455.
16. Eslami MH, Zhu CK, Rybin D, et al. Simple predictive model of early failure among patients undergoing first-time arteriovenous fistula creation. *Ann Vasc Surg.* 2016;35:46-52.
17. Lopez-Cardalda G, Lugo-Alvarez M, Mendez-Santacruz S, et al. Learnings of the complete power grid destruction in Puerto Rico by Hurricane Maria. 2018 IEEE International Symposium on Technologies for Homeland Security (HST); October 23-24, 2018; Woburn, MA, USA. DOI: 10.1109/THS.2018.8574120.
18. FEMA. 2017 Hurricane Season FEMA After-Action Report. Published July 12, 2018. Accessed April 7, 2022. [https://www.fema.gov/sites/default/files/2020-08/fema\\_hurricane-season-after-action-report\\_2017.pdf](https://www.fema.gov/sites/default/files/2020-08/fema_hurricane-season-after-action-report_2017.pdf)
19. Rodríguez-Díaz CE. Maria in Puerto Rico: natural disaster in a colonial archipelago. *Am J Public Health.* 2018;108(1):30-32.
20. Alcorn T. Puerto Rico's health system after Hurricane Maria. *Lancet.* 2017;390(10103):e24.
21. Kuss O. How to use SAS for logistic regression with correlated data. Proceedings of the 27th Annual SAS Users Group International Conference; 2002. 2002. <https://support.sas.com/resources/papers/proceedings/proceedings/sugi27/p261-27.pdf>
22. Lalonde TL, Nguyen AQ, Yin J, et al. Modeling correlated binary outcomes with time-dependent covariates. *J Data Sci.* 2013;11(4):715-738.
23. Norris K, Harford R, Flaquer J, et al. SUN-192 missed hemodialysis treatments and mortality in Puerto Rico before and after the 2017 hurricanes: a medium dialysis organization experience. *Kidney Int Rep.* 2020;5(3):S279-S280.
24. Lin C-J, Pierce LC, Roblin PM, Arquilla B. Impact of Hurricane Sandy on hospital emergency and dialysis services: a retrospective survey. *Prehosp Disaster Med.* 2014;29(04):374-379.
25. Martín Y, Cutter S, Li Z, et al. Using geotagged tweets to track population movements to and from Puerto Rico after Hurricane Maria. *Popul Environ.* 2020;42:4-27.
26. Hick J. Evacuating, treating, and tracking people on dialysis: lessons learned from the 2017 hurricane season. *Exchange.* 2018;1(6):12-14.
27. Mayer CC, Matschkal J, Sarafidis PA, et al. Association of ambulatory blood pressure with all-cause and cardiovascular mortality in hemodialysis patients: effects of heart failure and atrial fibrillation. *J Am Soc Nephrol.* 2018;29(9):2409-2417.
28. Kalantar-Zadeh K, Abbott KC, Salahudeen AK, et al. Survival advantages of obesity in dialysis patients. *Am J Clin Nutr.* 2005;81(3):543-554.
29. Saran R, Robinson B, Abbott KC, et al. US renal data system 2016 annual data report: epidemiology of kidney disease in the United States. *Am J Kidney Dis.* 2017;69(3):A7-A8.