Renal Failure Patients in Disasters

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ABSTRACT

Disasters occur regularly, and frequently large numbers of patients treated with maintenance dialysis or with the recent onset of acute kidney injury are put at risk owing to the lack of access to dialysis care precipitating also a kidney failure disaster. The absence of necessary dialysis treatments can result in excessive emergency department visits, hospitalizations, morbidity, or an early death. Those with kidney failure are often evaluated in disaster medical locations or hospitals without nephrologists in attendance. Here we offer guidance for medical personnel evaluating such patients so that dialysis-dependent individuals can be properly assessed and managed with the need for urgent dialysis recognized. A disaster dialysis triage system is proposed. (*Disaster Med Public Health Preparedness.* 2019;13:782–790)

Key Words: dialysis, ESRD, triage, disaster, kidney

Major disasters occur throughout the world and include tornadoes,[1] snowstorms,[2] earthquakes,[3] cyclones,[4] hurricanes,[5,6] floods,[4] tsunamis,[7] fires,[8] volcanic eruptions, and man-made disasters such as wars,[9,10] terrorist attacks,[11] explosions,[12] and radioactive contamination.[13] Each disaster type, and often each disaster, has its own unique set of characteristics. Large-scale disasters can result in massive critical infrastructure destruction, jeopardizing transportation and communications systems,[14] as well as systems for power, sewage, and water. Government services, including emergency services, the food supply chain, and multiple inter-related industries, are also likely to be affected.[15] Considerable chaos occurs, and stress is provoked in those with chronic diseases and the elderly.[16] Disasters also affect the health care sector. Hospitals and community dialysis units can be compromised or closed by damage to supplies or staff shortages.[17,18]

A considerable literature has described the principles of disaster management for renal patients.[3,18-26] Reports have included guidance for predisaster planning, strategies for the evaluation and treatment of patients, and management of dialysis-related issues. Other issues addressed include coordinating relief efforts, setting of priorities, resolving logistical issues, and recognizing pitfalls to be avoided. This literature has been primarily directed to nephrology specialists. However, initial medical evaluation and management of renal patients in disaster settings are often performed by non-renal specialists.[27] This paper is primarily directed to those readers, and, for this reason, we have included definitions of relevant nephrological terms and reviewed the main dialysis treatment modalities.

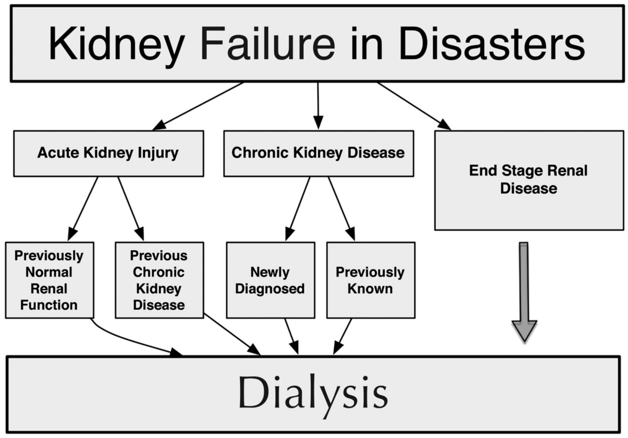
DEFINITIONS

To provide clarity, we include the following definitions and annotations:

- **Glomerular filtration rate (GFR).** GFR is the best overall index of kidney function in clinical practice, and decreased GFR is most often detected by the use of estimating equations based on the measurement of creatinine in blood samples and derived from individuals with stable kidney function. The current classification system for chronic kidney disease (CKD) stratifies kidney function into 5 stages, G1-G5, based on the GFR. Stage 3 is divided into 2 categories, G3a and G3b. Stage 3 includes patients with GFRs of 30-59 ml/min/1.73 m^2). Normal renal function, G1, is regarded as a GFR $\geq$ 90 ml/min/1.73 m^2. Stage 5 CKD is defined as a GFR < 15 ml/min/1.73 m^2, representing advanced kidney failure and is the stage when individuals usually enter chronic dialysis programs.[28]
- **Chronic kidney disease (CKD).** CKD in adult patients includes those with abnormalities of renal function for greater than 3 months and with a threshold of a GFR < 60 ml/min/1.73 m^2. The definition of CKD in adults generally applies to children, except for the duration that does not apply to newborns or infants, and a GFR < 60 ml/min/1.73 m^2 does not apply to children < 2 years of age for whom an age appropriate value should be used. Most causes of CKD are irreversible, and such individuals do not experience symptoms until late in the course of their disease. However, chronicity is not always synonymous with irreversibility because, in some cases, CKD is reversible, either spontaneously or with treatment. Unfortunately, many individuals with CKD are unaware of their

FIGURE 1

Kidney Failure in Disasters. Individuals who require dialysis may have acute kidney injury or chronic kidney disease. The majority is likely composed of those with end stage renal disease already enrolled in maintenance dialysis programs unless there are numerous crush injuries.



disease.[28] CKD patients, when subjected to a new kidney insult, have less resiliency in view of their antecedent renal impairment.[29]

- **Acute kidney injury (AKI).** AKI in adults and children is as an abrupt decline in kidney function and is defined as any of the following: (1) rise in serum creatinine ≥ 0.3 mg/dl (≥ 26.5 μmol/L) within 48 hours; (2) an increase in serum creatinine to ≥ 1.5 times baseline, which is known or presumed to have occurred within the prior 7 days; and (3) urine volume < 0.5 ml/kg/hour for 6 hours.[30] Diagnosing AKI in individuals who have pre-existing chronic renal failure is problematic using the usual definition for AKI as percentage increases in creatinine are blunted when CKD is present.[31] In a disaster setting where prior medical records may be lacking and laboratory testing may be unavailable, it is reasonable to assume normal pre-existing renal function unless individuals identify themselves as having CKD or as being dialysis-dependent. When the serum creatinine is unstable, such as in AKI and in patients receiving dialysis, GFR estimating equations are inaccurate.[32] AKI episodes can also be superposed upon CKD. Most AKI patients with pre-existing normal kidney function will recover renal function if they survive their acute illness but will have an increased risk for CKD.[33] Many disaster-related AKI patients will require dialysis support, albeit temporarily.
- **End-stage renal disease (ESRD).** ESRD is a medical condition in which kidneys cease to function, leading to the need for regular long-term dialysis to maintain life. Chronic dialysis patients are classified as ESRD patients. Kidney transplant patients, who require immunosuppressive medications to maintain kidney function, are also ESRD patients but not addressed elsewhere in this paper.
- **Disaster.** Disaster is a situation in which widespread and severe damage, injury, and loss of life or property occur, necessitating special efforts to cope with the magnitude of the event. During these episodes, the affected society undergoes severe disruption of its activities and infrastructure. A mass disaster occurs when the number of victims overwhelms the local system.[26]
- **Disaster nephrology.** This term refers to the area of nephrology dealing with the problems of acute and chronic kidney patients during and subsequent to disasters.[20] There are three types of kidney failure patients who may require disaster-related dialysis care: (1) AKI patients, (2) CKD patients who have pre-existing renal failure but are not yet enrolled in chronic dialysis programs, and (3) ESRD patients who are regularly receiving dialysis care[34] (Figure 1). Disaster nephrology has become an area of expertise within nephrology.
- **Kidney failure disaster.** A kidney failure disaster is an event that places large numbers of patients treated with maintenance dialysis or individuals with a recent onset of AKI at risk due to lack of access to dialysis care. Many major disasters have also been kidney failure disasters.[34]
- **Crush syndrome.** Systemic manifestations that may include AKI, electrolyte disturbances, sepsis, and other systemic manifestations that occur after a direct injury (ie, crush injury) by collapsing material and debris causing muscle swelling in the affected parts of the body. Earthquakes commonly produce injuries causing the crush syndrome. Earthquake victims who do not die immediately from direct trauma may experience the crush syndrome.[26]

DIALYSIS

There are two main types of dialysis. Hemodialysis requires an artificial dialysis membrane, blood tubing, and a dialysis machine. Toxins and extra fluid that accumulate in the blood

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in kidney failure are removed during dialysis. Patients usually receive their treatments in dialysis facilities, but some are treated at home where a highly purified water supply must be produced. A functioning blood access site is necessary for blood to leave the body, traverse blood tubing, and then pass through a dialysis membrane. Most patients have a fistula or graft for access, but some have an indwelling central venous dialysis catheter. Hemodialysis accesses do not always function well and at times need to be revised, declotted, or replaced. A blood pump assists in the circulation of blood through the blood tubing. In wealthy countries, where dialysis is widely available, most chronic dialysis patients are treated by thrice weekly hemodialysis, although other regimens are sometimes used to reduce dialysis-related side effects.[35]

Chronic peritoneal dialysis patients are usually treated at home and have an indwelling catheter in their abdomen. A dialysis solution (ie, the dialysate) is infused and drained through connected tubing. The peritoneal membrane serves as the dialyzing surface. Some patients use automated equipment (ie, a cycler) to perform their peritoneal dialysis exchanges. Peritonitis is a common complication of peritoneal dialysis, and the infection requires the urgent administration of antibiotics or, at times, a dialysis catheter removal, to eradicate the infection. Patients ordinarily perform their peritoneal dialysis exchanges multiple times daily.[36] Children receiving chronic dialysis are more likely to be peritoneal dialysis-dependent than adult ESRD patients,[37] but their numbers are likely to be overall few in any conceivable disaster scenario.[37,38] Nevertheless, disaster preparedness planners should consider their needs.[39]

In 2015, the United States had nearly 500,000 patients who were receiving maintenance dialysis with approximately 90% of patients being treated with hemodialysis and 10% receiving peritoneal dialysis.[37] In the United Kingdom in 2015, there were over 61,000 patients dialysis patients with a 7 to 1 hemodialysis to peritoneal dialysis ratio.[40] Canadian data for 2016 (excluding Quebec because of underreporting) indicate nearly 22,000 dialysis patients of which three-quarters were treated by hemodialysis.[41] Low income regions in the Middle East, South Asia, South East Asia, Oceania, Africa, and South East Asia have few chronic dialysis patients.[42] Only when a disaster strikes in locations where there are many chronic dialysis patients will there be substantial numbers of individuals who could be separated from their usual dialysis care, thereby provoking a kidney failure disaster.

KIDNEY FAILURE DISASTER

Dialysis-dependent patients are uniquely vulnerable when separated from dialysis treatments. Hemodialysis units may become inoperable due to destruction, loss of suitable water for dialysis (without a backup water supply), damage to disposables and equipment, and power outages. Patients may be unable to travel to their dialysis facilities.[18] Shortages of medical and nursing staffs can also be a significant obstacle, and relocating dialysis personnel to the disaster impact area can permit the operation of dialysis facilities that have been compromised by staff nonattendance.[43] Nearby acute care hospitals also can be compromised and not have the capacity for dialyzing a large influx of new patients who may only require dialysis care and otherwise do not require hospitalization. A mass evacuation of hundreds of dialysis patients to surrounding areas can easily overwhelm receiving outpatient dialysis centers.[44] Many dialysis patients will miss their scheduled dialysis sessions and experience morbidities, including hypertensive emergencies, severe electrolyte abnormalities, fluid overload, respiratory failure, hospitalizations, and emergency department visits.[5,45,46] A significant impact on mortality for chronic dialysis patients as a result of a disaster has been found in some,[6] but not all studies.[46] Not every disaster is a kidney failure disaster because the functioning dialysis infrastructure may be adequate to care for those who require dialysis.

EMERGENCY PREPAREDNESS

In the United States, Medicare requires chronic dialysis facilities to have a comprehensive emergency preparedness program to manage dialysis-dependent individuals at the times of crisis.[47] Disaster plans are focused on the types of disasters likely to occur in a given geographical area. Programs are ordinarily organized by nursing leadership,[48] and guidance is readily available to assist in the development of such programs.[49,50] Basic emergency information is provided, including the need to assemble disaster kits containing medications and medical supplies and to implement an emergency renal diet, if separated from usual dialysis care. Chronic dialysis patients are instructed to promptly identify themselves to emergency workers as dialysis-dependent to facilitate their subsequent dialysis treatments. Because electrical power loss commonly occurs as a result of a disaster, plans include procedures to safely and quickly disconnect patients from hemodialysis or automated peritoneal dialysis machines if the power becomes compromised.[49] Unfortunately, backup generators are not always available or required in dialysis units.[51]

PATIENT EVALUATION

Many renal patients, at first, will be evaluated by non-renal experts.[27] First responders may not fully appreciate kidney failure-related issues nor recognize when dialysis support is urgently necessary. Medical personnel may be working in disaster-related special needs shelters or other modestly equipped disaster medical facilities where initial evaluations and interventions take place. Appropriate renal disaster patient management, as in non-disaster medicine, depends on medical history, physical examination, and testing.

- **Medical history.** The acquisition of a medical history may be even more important in the chaos of a disaster where

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medical testing may not be readily available and clinical judgement is therefore preeminent.[21] A history of kidney disease should be solicited. Diabetes, hypertension,[52] and vascular disease[53] are all common causes of ESRD, especially in high income countries. These conditions should be recognized as they may require treatment. All renal failure patients are disposed to congestive heart failure (CHF).[54] Therefore, a recent reduction in exercise capacity may represent the presence of CHF. Abdominal pain may signify peritonitis in a chronic peritoneal dialysis patient. If chronic hemodialysis patients are unknowledgeable regarding their own medical history, their home dialysis unit, if operational, or its affiliated large dialysis organization may be able to provide additional relevant information, including the results of stable blood studies that could prove valuable to interpret current laboratory tests. Rapid referral to an operational affiliated dialysis facility may also be possible. A crush injury history, as seen after earthquakes or tsunamis, should be given special consideration because early intervention may be lifesaving.[26]

- **Physical examination.** Hypertension may represent separation from anti-hypertensive medications or inadequate blood pressure treatment but could also represent volume overload in a renal failure patient. The presence of fever suggests infection and may be the cause for AKI that could be reversed with appropriate antibiotic administration. Peritoneal dialysis-related peritonitis may also cause fever and signs of peritoneal inflammation. If present, a dialysis fistula or graft will need to be checked for a bruit or thrill to determine whether it is functioning properly for dialysis to proceed. The presence of a central venous dialysis catheter should be noted. The signs of CHF are the same in those with and without kidney disease.[54] A pericardial friction rub or the presence of encephalopathy or asterixis may be indicative of advanced renal failure.
- **Blood testing.** Point-of-care blood testing is useful to assist in diagnosing AKI, assessing others with renal failure, and determining the need for urgent dialysis.[55] However, such equipment may not be available, especially in low-income countries, where evaluating patients in the absence of laboratory data may be necessary.[21] Point-of-care instruments must deliver reliable results in the environment in which they are used because erroneous results can alter clinical decision-making. Test reagents also must be stored properly. Extreme environmental conditions have resulted in the failure of point-of-care blood analyzers in previous disasters. The i-STAT System's (Abbott Diagnostics, Santa Clara, CA) operating range is 16°C-30°C. Other systems have different environmental limits.[56]

PATIENT MANAGEMENT

Chronic dialysis patients and AKI patients, as well as those with CKD may all require dialysis as a result of a disaster. Newly identified dialysis-requiring patients will add to the burden of caring for pre-existing chronic dialysis patients (see Figure 1).

Urgent dialysis may be necessary in any individual with advanced renal failure (GFR < 15 ml/min/1.73 m^2). Accepted indications for urgent dialysis include (1) refractory fluid overload; (2) severe hyperkalemia (potassium > 6.5 mEq/L or rapidly rising potassium levels); (3) signs of uremia such as pericarditis, seizures, encephalopathy, or an otherwise unexplained decline in mental status; and (4) severe acidemia (pH < 7.1).[57] Neurological signs associated with uremia are late signs of uremia[58] as is a pericardial friction rub.[59] Urgent dialysis may be required when these signs are absent if any of the other indications for urgent dialysis exist.

When dialysis availability is inadequate, transporting patients outside of the region to other locations where dialysis care is available is the best policy. In large urban areas, chiefly in high income countries, the numbers of chronic dialysis patients impacted by a disaster may be substantial, presenting logistical issues to relocate all dialysis-dependent individuals. Establishing new dialysis facilities close to a disaster's impact zone has proved to be successful, mainly for AKI patients, but can provide care for only a limited number of dialysis-requiring individuals. The International Society of Nephrology's Renal Disaster Relief Task Force, working in close collaboration with Médecins sans Frontières, has been particularly effective in providing crucial dialysis assistance in the aftermath of many disasters.[60]

- **AKI patients.** Patients with disaster-related AKI will be few unless crush injuries are frequent. The incidence of crush syndrome can be as high as 25% in earthquake victims, and hundreds of dialysis-requiring patients have been identified after previous major earthquakes. Extensive recommendations have been published regarding the management of crush syndrome victims, including prevention strategies recommended for first responders and subsequent hospital care.[26] Individuals not previously dialysis-dependent would ordinarily not have had previous significant contact with chronic dialysis facilities[34] and received education in maintaining a sodium, potassium, and fluid-restricted emergency renal diet that may delay the need for dialysis.[24] Dialysis-requiring AKI patients associated with crush injuries will require dialysis support on average of 13-18 days, and death is common without dialysis, often from fatal hyperkalemia.[26] When a large number of critically ill patients are identified as a result of a mass disaster, treating everyone who needs care may be impossible. In these instances, a system of triage and ethical decision-making must be implemented.[61] This triage scenario is more likely in undeveloped countries.

Peritoneal dialysis is ordinarily less useful than hemodialysis in disaster-related AKI because of inefficient potassium removal, the need to surgically place a dialysis catheter, the

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requirement for peritoneal dialysis-specific supplies, and the risk of peritonitis. Nevertheless, peritoneal dialysis is an option if hemodialysis is unavailable and when there is the lack of electricity or a compromised water supply. Peritoneal dialysis may be preferable in small children.[36] Placement of a central venous dialysis catheter will be necessary for hemodialysis treatments in those who do not have a dialysis access.

AKI patients will likely require hospitalization in a facility where dialysis is available to treat comorbid conditions as well as to manage kidney failure. Mildly injured crush injury victims may not require prolonged hospitalizations as long as outpatient follow-up is possible. Critically ill patients with AKI may have the best outcomes in tertiary medical centers where early nephrology consultation is provided.[62] Transportation to nearby hospitals that lack nephrologists should be avoided.

- **CKD patients.** CKD patients include chronic dialysis patients, as well as those with chronic renal disease not enrolled in chronic dialysis programs. Both groups will require evaluation. In many disasters, most patients requiring dialysis will likely be chronic dialysis patients.[34] Maintenance dialysis patients ordinarily have some residual kidney function when they enter maintenance dialysis programs. However, residual kidney function typically continues to deteriorate during the years of dialysis.[63] Individuals who have remaining renal function will maintain urine output and thereby may prove to be more resilient to missed dialysis sessions insofar as experiencing hyperkalemia and fluid overload.

Chronic dialysis patients should be treated by their usual dialysis modality, hemodialysis, or peritoneal dialysis. Early prophylactic hemodialysis or the administration of a potassium lowering medication (eg, a potassium exchange resin) prior to a predicted disaster, such as a hurricane, can substantially reduce the adverse consequences of missed dialysis sessions, improve tolerance for dialysis treatment delays, and reduce emergency department visits.[51] However, providing early dialysis is not always feasible because there may be a large number of patients who would benefit from such treatments, but dialysis facilities may not have the necessary reserve capacity.[44] An early dialysis patient surge can be more easily accommodated by transiently reducing the usual duration of dialysis treatments.[4] Patients should be encouraged, if possible, to continue their renal diets. Lack of access to usual medications could result in the decompensation of previously stable medical conditions.

Chronic peritoneal dialysis patients are at risk when they lack dialysis supplies and thereby constitute chiefly a logistical challenge. Large volumes of dialysate are necessary to perform peritoneal dialysis exchanges. If a peritoneal dialysis is to proceed in a sheltered setting, peritoneal dialysis supplies will need to be obtained and stored, a clean work surface will need to be available to prepare dialysis solutions for use, and a secure space will need to be accessible for the patient to occupy while peritoneal dialysis exchanges are proceeding. A drain will need to be reachable for the disposal of used dialysate.[64] Home peritoneal dialysis patients will likely know the details of their dialysis prescription but will generally not have evacuated with their disposable dialysis supplies.

Despite improved disaster preparation and execution of dialysis plans by dialysis facilities, there still will be patients who will miss their regularly scheduled dialysis treatments and will not have received prophylactic early dialysis.[4] Moreover, following an essentially unpredictable disaster, such as an earthquake or tsunami, chronic dialysis patients will not have time to relocate.

RECOMMENDED APPROACHES

The recommended approaches are provided, as follows:

- **Hyperkalemia.** Potassium control is problematic in all renal failure patients but particularly so in those with crush injury-related AKI. Crush injury patients are subject to the precipitous development of life-threatening hyperkalemia and other metabolic disturbances that could require urgent dialysis.[3] Moreover, limited food choices in disaster relief sites and special needs shelters may result in foods being consumed that are high in potassium, resulting in dangerous hyperkalemia. Ideally, blood testing will be available to detect dangerous hyperkalemia.[65] Severe hyperkalemia can result in cardiac rhythm disturbances,[66] muscle weakness including paralysis, and death.[67]

Polystyrene sulfonate resin is recommended to be available at disaster medical sites to treat hyperkalemia by removing potassium from the body and thereby conceivably permitting the delay of dialysis care.[36] We recommend the use of this resin because of its general availability, despite its somewhat variable onset of action (2-6 hours), modest duration of action (6-24 hours), and lack of convincing efficacy data. However, occasional serious adverse effects[68] temper our enthusiasm for its use. Colonic necrosis has rarely been associated with its administration, primarily if administered rectally, so oral dosing is safest.[69] Sodium polystyrene sulfonate does exchange sodium for potassium, thereby potentially exacerbating CHF.[70] Patiromer and zirconium cyclosilicate are newer medications for treatment of hyperkalemia. Patiromer is unsuitable for use in emergency situations because it has a 7-hour onset of action. Zirconium cyclosilicate has a quicker onset of action (1 hour) and would be valuable for the emergency treatment of hyperkalemia,[68] but its expense and narrow availability limit its role in disaster settings. Unfortunately, a sodium load also results from its administration.[68] In view of its safety profile, zirconium cyclosilicate, if available, would be a better choice than sodium polystyrene sulfonate resin.

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TABLE 1

Interventions Checklist for Disaster Medical Sites

Intervention

Question	Rationale	Yes	No
Is dialysis required?	Triage 1 and Triage 2 require immediate dialysis. Triage 3 requires dialysis within 12-24 hours (see triage categories below). Significant hyperkalemia, acidemia, resistant CHF, or a uremic complication requires early or urgent dialysis.	☐	☐
Should hyperkalemia be treated?	Dialysis is the definitive treatment for hyperkalemia in dialysis-dependent patients. Treatment with alkali can be helpful if acidemia is present, and a glucose-lowering intervention is beneficial when hyperglycemia exists. Zirconium cyclosilicate or a potassium exchange resin will lower potassium levels and can be administered “prophylactically” to delay the need for dialysis.	☐	☐
Should hyperglycemia be treated?	Chronic medical conditions need to be addressed in disaster medicine. Control of hyperglycemia may result in a reduction in potassium levels.	☐	☐
Should acidemia be treated by the administration of alkali?	Treatment of acidemia could help modestly reduce K levels and increase HCO_3 levels, but the use of $NaHCO_3$ could provide an unsafe sodium load. Acidemia is better and more safely corrected with dialysis.	☐	☐
Should high-dose diuretics be administered?	Those with residual kidney function may respond to high doses of loop diuretics (furosemide 200 mg PO or bumetanide 5 mg PO) to increase urine output and potassium loss, thereby delaying the need for urgent dialysis for hyperkalemia or CHF.	☐	☐
Are medication changes necessary?	Medication adjustments are often required in renal failure patients. Avoid nonsteroidal anti-inflammatory drugs and other nephrotoxic medications, if possible, in acute kidney injury and chronic kidney disease patients but may be considered in ESRD patients if dialysis is available.	☐	☐

Check Triage Level:
☐ Triage 1: Immediate dialysis with hospital admission
☐ Triage 2: Immediate dialysis without hospital admission
☐ Triage 3: Dialysis within 12-24 hours
☐ Triage 4: Dialysis within 24-48 hours
☐ Triage 5: Not likely dialysis-requiring
☐ Unassigned Triage Level
Comment:

Other rapid interventions that can assist in the control of hyperkalemia include insulin administration,[71] particularly in the hyperglycemic patient, and alkali administration if hypobicarbonatemia is present.[72] Sodium-free alkali preparations are under development to avoid the sodium load associated with sodium bicarbonate administration.[73] Electrocardiogram (ECG) changes of hyperkalemia or muscle paralysis[67] indicate severe degrees of hyperkalemia.[66] However, ECG changes for hyperkalemia are not always seen in patients because ECGs have a low sensitivity to detect hyperkalemia when advanced renal failure is present.[74] Dialysis remains the best treatment for hyperkalemia in the dialysis-dependent patient or those with AKI because dialysis rapidly removes potassium from the body.[75] In a hyperkalemic emergency, intravenous calcium can reduce the cardiotoxicity of hyperkalemia; but its effect is brief, 30 to 60 minutes, and should be combined with other interventions for hyperkalemia control.[75] High doses of loop diuretics can provide a degree of kaliuresis even with advanced CKD.[76]

- **Serum chemistries**. In the chronic dialysis patient who has merely missed scheduled dialysis treatments, dialysis should not be delayed while waiting for the results of blood chemistries.[21] Blood tests probably are unnecessary if dialysis was administered within the previous 48-72 hours. Most chronic dialysis patients are treated with standard solutions, and blood testing is performed infrequently in outpatient dialysis settings. AKI patients will likely require blood tests unless there is ECG evidence for severe hyperkalemia, suggesting the need for urgent dialysis. AKI can occur in the absence of marked elevations in creatinine in individuals with a low body mass index.[77]
- **Fluid balance.** CHF is frequent in renal failure patients. Chronic dialysis patients may have little or no urine output, and individuals with renal failure have a reduced ability to normally excrete a salt and water load. Impaired cardiac function, common in individuals with chronic renal disease, will additionally compromise the ability to tolerate fluid accumulation.[54] Often chronic dialysis patients have difficulty adhering to their recommended fluid restrictions because thirst is a common issue.[78] Dry weight is achieved in hemodialysis patients when extra fluid is absent. Optimal fluid control (ie, dry weight) is not realized in some individuals in view of large, interdialytic weight (ie, fluid) gains. Poorly compliant patients may miss or decline recommended dialysis sessions.[2] Even in the absence of a disaster, chronic hypervolemia may exist. Such individuals are likely to be at a significant risk for

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volume overload, as well as electrolyte disturbances, and should be identified so they may be referred for early dialysis.

Volume depletion can provoke AKI and may be reversed by fluid administration, thereby avoiding the need for dialysis.[79] Intraosseous fluid administration can be considered when reliable intravenous access is unavailable.[80] Volume-overloaded patients may respond to high doses of loop diuretics when there is some retained intrinsic renal function.[76]

Crush injury patients have a high mortality. The copious administration of potassium-free intravenous fluids as soon as possible after experiencing a crush injury can be impactful. Early intravenous fluid administration can even occur prior to extrication from a crush injury site and may prevent crush syndrome manifestations, including the need for dialysis.[26]

- **Vascular access.** A dialysis access, be it a fistula, graft, or central venous dialysis catheter, is the means to access the blood supply for hemodialysis treatments. If a fistula or graft is not functioning, a thrombectomy or thrombolysis will be necessary.[81] If a dialysis catheter has not been recently used for dialysis, clotting within the catheter may make it incapable for use unless catheter declotting occurs. An interventionalist, who is a radiologist or nephrologist or a vascular surgeon, can intervene to resolve dialysis access issues. At times, a newly placed dialysis catheter will be necessary. The absence of a usable dialysis access will delay dialysis treatment until a functional dialysis access is in place.[82]

INTERVENTIONS FOR RENAL FAILURE PATIENTS IN DISASTER SETTINGS

Table 1 is a checklist that can be used at disaster medical sites to guide interventions and to assign a dialysis triage level once patient assessment has occurred. Treating hyperkalemia, CHF, hyperglycemia, and acidemia are addressed. The value of high dose diuretics is noted, as well as the need to consider medication adjustments.[83] A dialysis triage system is recommended to classify patients according to the urgency of their dialysis needs. An individual identified as requiring urgent dialysis could die without the early application of dialysis, as could someone wrongly assigned to a category that is too low and have dialysis inappropriately delayed. A numerical system is used so as not to be confused with color-coded based triage systems used in emergency departments, on the battlefield, and in other situations when there are insufficient resources available to treat all who simultaneously need medical care.[84] A color-coded triage status can co-exist with a dialysis triage category because a color and dialysis triage number can be both assigned to the same individual. Red color coding in color-based systems ordinarily indicates that one cannot survive without immediate treatment and that would also correspond to dialysis triage level 1 or 2.

CONCLUSION

Mass disasters will continue to occur. In fact, the intensity and frequency of hurricanes, cyclones, tropical storms, and floods are increasing and likely the direct result of global warming.[85] Any major disaster, whether natural or man-made, has the potential to place renal patients in jeopardy. The best approach in predicted disasters is for individuals who were previously dialysis-dependent to evacuate early to locations where dialysis care can be reliably provided. Regrettably, this does not always occur.[24] Many individuals require evacuation who could receive their usual dialysis care if backup generators were available in their home dialysis units.[51] In unpredicted disasters, there is no prior warning, and large numbers of AKI patients can be created.[3]

Aggressive adherence to a renal diet,[24] use of high doses of diuretic in those with residual renal function,[76] use of potassium-lowering medications,[69] and early dialysis before predicted disasters can delay the need for dialysis in those who are dialysis-dependent.[51] However, large numbers of patients may still be identified who will need to be evaluated for dialysis needs and often by non-renal specialists.[27]

We hope that by understanding the basic concepts of disaster nephrology presented here, medical care providers in a disaster medical care setting will be better able to evaluate, manage, triage, and effectively communicate medical information regarding renal failure patients. In this way, the risk to patients can be reduced, and nephrologists, who may not be at disaster medical sites, can better manage dialysis needs when advised of patients who may urgently need dialysis. Although this paper was prepared with the non-nephrologist evaluator in mind, nephrologists may also find our approach valuable.

The calamitous 2017 Atlantic hurricane season in the Western Hemisphere included the Irma and Maria hurricanes that were also renal disasters[86] reminding the renal community of the vulnerability of their patients. After major disasters, disaster planners are energized to propose more robust disaster management systems for renal patients; but, in time, that enthusiasm often wanes so that only incremental improvements are implemented until after the next renal disaster.

Unfortunately, multiple disasters appear necessary for incontrovertible progress.

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