Abstract

Two Diseases Whose Rates Warranted Aggressive Search and Rescue in Puerto Rico Post Maria

Mark Y. Czarnolewski

Independent Scholar

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- The CDC publishes rates of diseases for each state (including U.S. territories, such as Puerto Rico). These publications of disease rates are published in the *Morbidity and Mortality Weekly Reports (MMWR).* Two diseases, diabetes (both Type 1 and Type 2) and End Stage Renal Disease (ESRD), are medical conditions that require monitoring and intervention. ESRD requires dialysis or a kidney transplant for survival and diabetes accounts for 44% of ESRD patients (Burrows, et al., 2017).

- Diabetes is often comorbid with a number of other medical conditions and is the third leading cause of death in Puerto Rico (PR) and in the United States (Puerto Rico Chronic Disease Action Plan 2014-2020).

- Geis, et al. (2012) report that 12.7% of adults greater than 18 in PR have diabetes. Given 3.3 million residents in PR and that those greater than 18 account for approx. 80% of the population (Wikipedia for PR) .8 x 3.3 million x .127 = 335, 280 (approx.) people > 18 with diabetes in PR.

- Cumba-Aviles and Saez-Santiago (2016) report estimates of diabetes rates in PR from 2011-2013 as 13.3% to 16.4%. Of those less than 20 years old, about 16,148 have diabetes, with Type 1 four times Type 2, then Type 1 = 12,918 diabetics. Cumba-Aviles and Saez-Santiago (2016) cite studies showing that depression has been linked to increased diabetes symptom severity, complications, treatment resistance, mortality rates and health care costs. Thus, this population (and others) are susceptible to psychological and psychiatric reactions from environmental stressors, such as hurricanes, other natural disasters and other types of stressors.

- Tierney, et al. (2013) using a self-report survey for diagnosed diabetes found that the mean unadjusted estimate was 14.3% (range, 9.9%–18.0%) on PR. The average width of the 95% CI was 6.2% (range, 2.8%–13.0%). The mean age-adjusted estimate was 13.3% (range, 9.8%–15.8%). Adjusted and unadjusted estimates differed little, probably due to similarity of the age-structure between Puerto Rico and the United States. Their Table 3 presents the unadjusted diabetes prevalence by county for Puerto Rico.

- In Cumba-Aviles and Saez-Santiago (2016) literature review, they note that in 2012, 50% of adults in PR who presented at least 1 of the 9 most common chronic illnesses were comorbid with depression symptoms in a range from 29.2% (heart attack) to 42.3% (stroke). In addition, among Puerto Rican adults with these chronic illnesses, the prevalence of diabetes ranges from 21.7% (asthma) to 46.3% (heart attack), while as much as 69.5% of Puerto Rican adults with diabetes have at least one additional chronic illness. Age-adjusted prevalence of lifetime depression among PR adults with diabetes was 25.4% in 2013.

- Salas, et al. (PLOS|One, 2016) For PR, among the elderly (>65), 37.1% are diabetic. Given there are 582,036 elderly in PR, there are approximately 215,935 elderly with diabetes in PR (see Tables 1 and 2 for additional computations) (https://en.wikipedia.org/wiki/Demographics_of_Puerto_Rico)

- Burrows, et al. (2014; 2017) report that PR had 6,091 ESRD patients over 18 in 2010, with 1,462 starting treatment. The present paper provides estimates with larger numbers by using data from a Government report (Table 3).

- Hurricane Maria is by far the most destructive hurricane to hit Puerto Rico in modern times (Pasch, et al., 2019). Maria knocked down 80 percent of Puerto Rico's utility poles and all transmission lines, resulting in the loss of power to essentially all of the island's 3.4 million residents. The combined destructive power of storm surge and wave action from Maria produced extensive damage to buildings, homes and roads along the east and southeast coast of Puerto Rico as well as the south coasts of Vieques and St. Croix.

- Maria's center crossed the southeast coast of Puerto Rico, and the hurricane's maximum winds at that time were just below the threshold of category 5 intensity (Pasch, et al., 2019). The hurricane's center crossed the island, roughly diagonally from southeast to northwest, for several hours and emerged into the Atlantic. The combined effect of the surge and tide produced maximum inundation levels of 6 to 9 ft above ground level to the north of Maria's southeast landfall. The NOAA estimate of damage in

Puerto Rico and the U.S. Virgin Islands due to Maria is 90 billion dollars, which makes Maria the third costliest hurricane in U.S. history.

- The present analysis focuses on accessing readily available public information (e.g., Government reports, peer-reviewed journals, media, etc.) to help identify and amass relevant information to help guide interventions, such as medical and psychological interventions. The numbers computed in this paper highlight the need for quick retrieval of data that can help guide aggressive search and rescue to ensure health stabilization and maintenance in times of crises, such as Hurricane Maria and its aftermath (Ghosh, et al., 2018.)

Method and Results

- This section shows how estimates of counts for diabetes (Type 1 and Type 2) and ESRD can be readily computed or obtained for the population in Puerto Rico. Table 1 contains references with corresponding data and computations for estimating the number of Type 2 and Type 1 diabetics. Detailed computations are provided for senior citizens (greater than 65).

- The general population's estimated rates of diabetes on Puerto Rico are: Cumba-Aviles and Saez-Santiago (2016) reporting rates of 13.3 to 16.4%, Geis, et al. (2012) reporting 12.7% and Tierney, et al. (2013) reporting 13.3% or 14.3%. Given these general population rates for diabetes, and an estimated population of 3.3 million for Puerto Rico, one can conservatively estimate 3.3 million x 12.7% x 80% who are approx. >=18, i.e., 335,280, to about 3.3 million x 16.4%, i.e., 432,960, diabetics on PR.

- Senior citizens in Puerto Rico have higher rates of diabetes than the PR population, as a whole, with estimated rates of 37.1% (Salas, et al. 2016). *Because diabetes is comorbid with many diseases (Burrows, et al., 2017; Puerto Rico Chronic Disease Action Plan 2014-2020) and senior citizens comprise the largest number of deaths for diabetes and a number of diabetes' comorbid diseases than other age groups (DHHS/CDC, 2017), the much higher rate of diabetes among senior citizens requires a special focus.*

- Table 1 provides computations for estimating the number of Type 2 and Type 1 diabetics, which includes:

- The estimated number of senior citizen diabetics in PR is 215,935; the estimated number of senior citizen in PR Type 1 diabetics is **10,797**.

- The estimated number of Type 1 diabetics by Age Group, with estimated total of **24,694** or **35,863.** Cumba-Aviles and Saez-Santiago (2016) cite a rate of 1.8% for PR, while the national rate is 0.24% in 2015 (American Diabetic Association, March 22, 2018).

- Type 1 diabetics require insulin; therefore, refrigeration for their medication.

- Table 2 provides estimates on those >= 65 and diagnosed with diabetes

- Estimates of >=65 and receiving insulin, whether Type 1 or Type 2 diabetics = 17,966, all requiring refrigeration.

- Estimates of >=65 and receiving insulin, or insulin or hypoglycaemic agents (for example, Metformin) = 62,189. Medications, such as Metformin require, at least, temperate temperature with moderate humidity.

- Table 3 provides estimates of number of Puerto Ricans with ESRD in 2015 and details numbers by incidence or prevalence and treatment status. The computed estimate for prevalence is 7,843 and for incidence is 1,498.

- Burrows, et al (2014; 2017) report that PR had 6,091 ESRD patients over 18 in 2010, with 1,462 starting treatment

Discussion

- The present paper shows how to determine the number of people with two medical conditions requiring intervention (diabetes and ESRD). Knowing these numbers for these and other medical conditions provide critical information for those trying to amass and deliver critical life-saving resources in dangerous environmental conditions.

- This report estimated the number of diabetics (Type 1 and 2), especially those >=65, number of ESRD patients, all dependent on electricity with the need for any or all the following: (a) insulin refrigeration, (b) other diabetes medication, such as Metformin that is kept at room temperature and moderate humidity, and (c) dialysis units fully functioning round the clock.

- Further, part of the diabetes and ESRD estimates are among the many PR residents who access primary health care services through community health centers (CHCs) which rely heavily on federal Medicaid funding (CMS) ; ninety three CHCs served 300,000 residents, primarily in rural areas (Michaud & Kates, 2017).

- Tierney, et al (2013, Table 3) provide diabetes prevalence estimates within each county in PR. In general, *low* prevalence counties are concentrated on the eastern half of Puerto Rico and *high* prevalence counties on the western half. The western half tends to have a *higher* percentage in poverty, a higher average household size, a *lower* percentage of those >=25 years who completed high school, and *lower* median household income.

- While the etiologies of Type 1 and Type 2 diabetes are totally different, recommendations to control blood sugar, blood pressure and cholesterol, and engage in physical activity are the same for both types (Tierney, et al., 2013).

- Bonilla-Felix and Suarez-Rivera (2018, Figure 1) provide a map of the 52 hemodialysis (HD) units on the island, which are used for ESRD patients, with 48 of them able to continue working immediately after Hurricane Maria, including the only pediatric dialysis unit on PR. But, all had to use generators and water tanks.

Deaths

- The estimates of deaths are critical both for knowing the magnitude of the disaster and knowledge gained as to what to expect in terms of numbers of deaths and causes of deaths (Ghosh, et al., 2018).

- Robles, et al. (Dec 9 2017) report that the Center for Investigative Journalism published its own estimate that nearly 1,000 plus more people than usual died in the months of September and October. Records from Puerto Rico's government show that some of the leading categories of causes of death in September were, in order: diabetes, Alzheimer's/Parkinson's, emphysema/other breathing disorders, sepsis and pneumonia. Cruz-Cano and Mead (2019) list the number of excess deaths by top five diseases for September and October as (a) heart disease, (b) other, (c) diabetes, (d) Alzheimer's and (e) septicemia, with a total of 1,205 deaths – *86.1% of all deaths were >=60.*

- Nationally, deaths from, in order: heart disease, chronic low respiratory, cerebrovascular, Alzheimer's, diabetes and influenza/pneumonia diseases are among those most likely found among those >=65 (DHHS/CDC, 2017); *therefore, the conditions in the aftermath Maria likely endangered an already vulnerable population.* Robles, et al. (Dec 9 2017) note that "the highest surge was in deaths from sepsis — a complication of severe infection — which jumped 50 percent over last year. That change is notable and could be explained by delayed medical treatment or poor conditions in homes and hospitals."

- Santos-Lozado and Howard (2018) estimated that given the 95th percentile for the computed confidence interval of deaths between 2010 to 2016, that there were 518 excess deaths in September and 567 deaths in October.

- Santos-Burgoa, et al. (2018) estimated that 2,975 excess deaths (95% CI of 2,658-3,290) from September, 2017 to February, 2018. The ratio of observed to expected mortality was highest for individuals living in municipalities with the lowest socioeconomic development. However, the actual numbers were highest for high SES municipal dwellers. The largest impact, regionally (Santos-Burgoa, et al.'s Figure 3) was in PR's northeast, and to a lesser extent in the southwest. Men aged 65 years or older had high mortality

rates. Santos-Burgoa, et al. call for equitable disaster preparedness and response to protect vulnerable populations in disasters.

- Kishore, et al (2018) found 4,645 excess deaths during this period. Santos-Burgos, et al. note that the difference between these latter two studies are a function of the methodologies employed (Kishore, et al., employed a random survey of households January – February, 2018), but that both estimates were much higher than the official Government count of 64 deaths.

Logistics

- FEMA coordinated with other federal agencies (e.g., Army Corps of Engineers, Department of Energy), private sector, to move generators, water pumps, water treatment units and other equipment to have electrical power restoration (DHS/FEMA, 2018; Wolf & Curren, December, 14, 2017). FEMA provided generators to 30 critical medical facilities: 14 hospitals and 16 diagnostic treatment centers. But, FEMA could not decide which lower level medical facilities would receive generators. FEMA gave the PR agency for public water and wastewater system a number of these generators.

- One of the lessons emerging from the 2017 hurricane season is that generators typically are built to run for a week or two, not long-term, and they require regular maintenance (Wolf & Curren, December 14, 2017). Private physicians' offices, too, need to talk with their building owners about whether the building has a generator maintained regularly and of suitable size to allow the offices to remain open in long-term power outages.

- Over 600 dialysis patients moved away from PR, primarily to Florida as well as to a number of states (Bonilla-Felix & Suarez-Rivera, 2018; DHHS, September 28, 30, 2017) with coordination with Centers of Medicare and Medicaid End Stage Renal Disease Networks. But there are approximately 6,089 ESRD patients on PR (Burrows, et al., 2014); therefore, approximately, 5,489 patients required care, about 95% (hemodialysis) had to get to units or about 5% needed clean water and supplies for self-care at home (peritoneal dialysis).

- Hurricane Maria significantly damaged key transportation, communication and electricity infrastructure which, together, exacerbated challenging health conditions (Bonilla-Felix & Suarez-Rivera, 2018; Michaud & Kates, 2017).

For example, patients did not receive messages from the Puerto Rico Department of Health that the patients go to the dialysis unit that is closest to them which they can reach. FEMA provided satellite phones for health care and government officials, but the service for both on the island and off the island communication was limited because of weather and lack of training with the technology (DHS/FEMA, July 12, 2018).

- In the adult population, the conditions of those with diabetes and hypertension are at risk of becoming uncontrolled after natural disasters due to their (a) inability to follow an appropriate diet, (b) limited accessibility to medications and (c) poor communication with providers (Bonilla-Felix & Suarez-Rivera, 2018). These authors state that the U.S. DHHS has developed an internet tool that identifies Medicare beneficiaries who rely on electricity-dependent medical equipment.

- Exacerbation of preexisting psychiatric conditions due to anxiety, difficulties in their daily living activities, and inability to maintain pharmacotherapy is frequently observed in natural disasters. This could lead to poor compliance in therapy, increasing the risk of this vulnerable population (Bonilla-Felix & Suarez-Rivera, 2018).

- Military Sealift Command Public Affairs (Nov 21 2017) reported that the "USNS Comfort treated 1,899 patients, performed 191 surgeries (44 general surgeries, like hernia repair, 25 major orthopedic surgical cases, including ruptured aortic aneurysm, 17 amputations and 15 urological procedures) , provided 76-thousand liters of oxygen and 10 tons of food and water." This included the Comfort receiving five critical patients who were medevaced by the Sea Knights of Navy Helicopter Sea Squadron (HSC) 22 and Army Blackhawks from Ryder Memorial Hospital in Humacao, Puerto Rico, after its generator failed.

- Robles and Fink (Dec 6 2017) reported that the "Comfort's mission leaves behind questions about whether it was adequately used during a time of desperate medical need. The ship was prepared to support 250 hospital beds, but over its 53-day deployment, which included travel to and from the island, it admitted an average of only six patients a day, or 290 in total. An additional 1,625 people were treated aboard the ship as outpatients, all at no cost."

- Craig Hooper (Nov 6 2017) notes that it took USNS Comfort two weeks to get to PR after Maria hit and that there were three more weeks where the "Comfort appeared seemingly underutilized by being connected to the injured population by a thin stream of helicopters."

- DHHS (December 20, 2017) lists DHHS involvement, (e.g., deployed 3,037 personnel and assisted 31,011 patients) and allocation of resources "to assist local hospitals, dialysis facilities, clinics, and medical supply manufacturers in obtaining the resources needed to continue or restore operations" (Wolf & Curren, December, 14, 2017). *At issue, is whether there could have been a larger, more comprehensive positive impact within a shorter time frame with better preparation (DHHS, January, 2012), coordination through greater investment in resources (DHHS, January, 2012; DHS/FEMA, July 12, 2018) and better apriori use of available public health information, as suggested by this paper.*

- The present analysis highlighted a need for preparation for when natural disasters are predicted to strike or have already started to strike. However, the primary focus of this analysis was accessing readily available public information (e.g., Government reports, peer-reviewed journals, media, etc.). Therefore, when an all-encompassing disaster, such as Hurricane Maria, and other hurricanes, floods, fires, earthquakes, etc. strike, public health information likely is available to help guide and amass appropriate interventions, such as medical, psychological, social service and nutritional interventions.

- Hurricane Maria significantly damaged key transportation, communication and electricity infrastructure, which exacerbated search, rescue and administration of extensive aid needed to deal with challenging health conditions (Bonilla-Felix & Suarez-Rivera, 2018; DHS/FEMA, July 12, 2018; Michaud & Kates, 2017). Such conditions require an integrated delivery of care with larger investment in resources than currently employed (DHS/FEMA, July 12, 2018; Robles, July 12, 2018) that increases the likelihood to successfully handle such a large scale disaster within a shorter time-frame where there was such massive destruction of infrastructure.

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Table 1. References and Computations for Determining Approximate Number of Type 1 and Type 2 Diabetics at the Time of Hurricane Maria in Puerto Rico

Source			
Wikipedia PR Demog.	Total Approx. Population =		3.3 million
	Age 0 – 14	18.77%	
	Age 15 – 64	65.36%	
	Age 15 – 19	7.39%	
	Age 20 - 64	57.97%	
	Age > 64	15.87%	582,036
Salas, et al. (2016)			
	Age >=65 and diabetic	37.1%	215,935
	.371 x 582,036 = 215,935 elderly with diabetes (approx.)		
cdc.gov/diabetes/basics/type 1		5%	**10,797**
	.05 x 215,935 = 10,797 elderly with Type 1 diabetes (approx.)		
Cumba-Aviles & Saez-Santiago (2016)			
	Diabetics < 20 = 16,148 (1.8%); if U.S. norm rate= 2,186 (.24%)		
	For <20, Type 1 is 80%; therefore,		**12,918, or 80% x 2,186= 1,749**
Geis, et al. (2012)	Age 19-64 and diabetic 12.7%		**12,148**
	.5797 (approx. 19-64) x 3.3 (Total) x .127 = 242,952 diabetics		
	x .05= 12,148		
	Total Approx. Type 1 Diabetics		**24,694 or 35,863**
Tierney, et al. (2013)			
	Age > 20 and Diabetes rate unadjusted is 14.3% and rate adjusted is 13.3%		
	Age > 18, .7384 x 3.3 million = 2,437,720 x .143		348,451
	Type 1 is .05 x 348,451 = **17,422**, or Type 1 is .05 x 324,084=**16,204**		

Table 2. References and Alternative Computations for Determining Approximate Number of Type 1 and Type 2 Diabetics at the Time of Hurricane Maria with Estimate Number who are Diagnosed in Puerto Rico.

Source			
Wikipedia PR Demog.	Total Approx. Population = 3.3 million		
	Age 0 – 14	18.77%	
	Age 15 – 64	65.36%	
	Age 15 – 19	7.39%	
	Age 20 - 64	57.97%	
	Age > 64	15.87%	582,036
Salas, et al. (2016)			
	Age >=65 and diabetic	37.1%	215,935
	.371 x 582,036 = 215,935 elderly with diabetes (approx.)		
	Age >=65 Diabetics diagnosed and controlled	15%	
	Age >=65 Diabetics diagnosed and uncontrolled	17%	
	Age >=65 and controlled + uncontrolled (17%+15%=32%) .32 x 215,935=		69,099
	Age >=65 and diagnosed who receive insulin: .26 x 69,099 =		17,966
	Age >=65 who get insulin or hypoglycaemic agents: .90 x 69,099 =		62,189
cdc.gov/diabetes/basics/type 1		5%	**10,797**
	.05 x 215,935 = 10,797 elderly with Type 1 diabetes (approx.)		

Table 3. References and Computations for Determining Approximate Number of End Stage Renal Disease Patients at the Time of Hurricane Maria in Puerto Rico.

Using the United States Renal System Data Report, one finds the following:

- For 2015 Network 3, which includes New Jersey, Puerto Rico and Virgin Islands:

  Incidence of ESRD = 5,376 and Prevalence of ESRD = 28,142

- Both New Jersey and Puerto Rico have approximately 15.8% of the population who are Age >= 64 (Wikipedia for 2017)

- 64-75 is the Age bracket with the largest number of ESRD patients

In terms of total population, NJ = 8.9 million (71.24%), PR = 3.47 million (27.87%) and VI = 100k (<1%); therefore:

- Approximately, 28,142 x .2787= 7,843 ESRD prevalence in Puerto Rico (PR)

- Approximately, 5,376 x .2787= 1,498 ESRD incidence in PR

- Approximately, 13,130 x .2787= 3,659 ESRD patients on hemodialysis

- Approximately, 970 x .2787= 270 ESRD patients on peritoneal dialysis

In contrast, Burrows, et al (*2014*) report that PR had 6,091 ESRD patients over 18 in 2010, with 1,462 ESRD patients starting treatment.