Community Pharmacy Operations in Puerto Rico During the 2017 Hurricane Season: A Descriptive Analysis of Rx Open Data

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ABSTRACT

Objectives: This article aims to: (1) describe the 'Return to Open Pharmacy Operations' in Puerto Rico following the hurricanes Irma and Maria in the 2017 hurricane season, and (2) compare the recovery rate (Return to Open Pharmacy Operations) during the 2017 hurricane season between the US Commonwealth of Puerto Rico and the state of Florida.

Methods: We performed a cross-sectional study of pharmacy operations in Puerto Rico utilizing Rx Open data for pharmacies in Puerto Rico during the 2017 hurricane season. To compare open rates of pharmacy operations over time in different contexts, we also analyzed Rx Open data for the state of Florida for Hurricane Irma.

Results: Only 11.1% of pharmacies remained open in Puerto Rico 3 days after Hurricane Maria made landfall, and Puerto Rico pharmacy operations recovered slowly, at an average daily rate of 3.9% before reaching pre-landfall baseline operations. Puerto Rico pharmacy operations after Hurricane Maria recovered 10 times slower on average, compared to pharmacy operations in Florida after Hurricane Irma which reached baseline operations less than 1 week following Hurricane Irma's landfall.

Conclusion: Our results demonstrate the unique severity of Hurricane Maria's impacts on Puerto Rico's health system.

Key Words: emergency preparedness, hurricane, natural disasters, pharmacy operations, Rx Open Map

In September 2017, the United States (US) territory of Puerto Rico was hit by 2 hurricanes.[1,2] Hurricane Irma, a Category 5 hurricane that passed 50 miles north of Puerto Rico on September 6,[1] brought significant winds and rainfall to Puerto Rico, causing a near-total loss of electricity and water supply for several days. Hurricane Maria made landfall in Puerto Rico as a high-end Category 4 hurricane 2 weeks later on September 20.[2,3] The destruction to Puerto Rico was unprecedented, with 90 billion dollars in estimated damages due to widespread devastation of Puerto Rico's infrastructure.

The resulting public health impacts following disasters triggered by natural hazards are mediated in part by the ability of the overall health system to respond to the needs of the impacted population. The destruction of Puerto Rico's health system and supporting infrastructure by Hurricane Maria caused consistent interruption of healthcare delivery, even months following landfall. In addition to initial impact on the health and safety of residents, delayed medical treatments and exacerbation of chronic conditions led to significant morbidity and mortality.[4-7]

Due to their wide geographic distribution and high prevalence throughout communities, pharmacists are some of the most accessible healthcare providers in the aftermath of disasters triggered by natural hazards.[8-11] In Puerto Rico, community pharmacists immediately responded to the needs of patients following Hurricanes Irma and Maria, providing acute triage to patients, administering immunizations, and refilling prescriptions.[12,13] This is similar to the role pharmacists play across the United States, although it is worthwhile to note that independent, community pharmacies in Puerto Rico are more prevalent than on the mainland.

Pharmacies, and other forms of healthcare infrastructure, are ultimately dependent on other forms of infrastructure to fully operate. Throughout the response, community pharmacists fought an uphill battle against surges in patient needs,[14,15] and infrastructure-related operation barriers; even 4 months following Hurricane Maria's landfall, electrical power had been restored to only 65% of Puerto Rico.[2]

Measuring Pharmacy Status in Disasters

Rx Open (www.rxopen.org) is a free, online public service provided by Healthcare Ready that maps the location and operating status of pharmacies in areas in the US impacted by disasters to help patients access

medicine during emergencies. Rx Open was created in 2008 after pharmacy status was identified as an information gap for survivors and responders during major disasters like Hurricane Katrina.

Rx Open is made possible through partnerships with the National Council for Prescription Drug Programs, pharmacy operators and network managers. Before a disaster event with notice, Healthcare Ready requests pharmacy partners to begin providing lists of all pharmacies reported to be operating within the last 12 hours. No confidential information is shared or received in this process. The status of 95% of all US and US-territory pharmacies can be mapped on Rx Open.

In addition to providing real-time information to patients in disaster zones, Rx Open provides a unique opportunity to investigate pharmacy operation during disaster response. This research aims to use Rx Open data as a novel method for describing pharmacy operations in Puerto Rico in 2017 following Hurricanes Irma and Maria and compare the reinstatement of pharmacy operations in Puerto Rico to the mainland state of Florida in the 2017 hurricane season.

METHODS

Following the declaration of a state of emergency for all of Puerto Rico in anticipation of Hurricane Irma,[17] Rx Open was activated by Healthcare Ready for the entirety of Puerto Rico on September 5, 2017. We performed a cross-sectional study of pharmacy operations in Puerto Rico utilizing Rx Open data for pharmacies in Puerto Rico from September 5, 2017 through November 10, 2017 (hereafter the reporting period). Florida's open rates and recovery rates were determined using the same methodology from September 8, 2017 through October 12, 2017. Rx Open data was collected twice daily from September 5 through October 13, then once weekly thereafter. For each pharmacy in the covered geographic area, data is reported to the system as 1 of the following:

- Open
- Closed
- Unknown
- Unknown: Not Currently Participating

The first 3 categories describe the operations of pharmacies currently participating in the network. *Open* indicates a pharmacy that has been reported to be operating in the last 12 hours. *Closed* indicates a pharmacy that has notified pharmacy operators of a closure or turned off its data feed to pharmacy operators. *Unknown* indicates a pharmacy that is reporting to a pharmacy operator, but the pharmacy's status is unknown because the pharmacy has not reported any data to the operator in the last 12 hours or is known to be experiencing another disruption. Examples of what the *Unknown* status may indicate include: a pharmacy open to provide other

services such as the sale of over-the-counter supplies or groceries, but is not filling prescriptions, or a pharmacy that is no longer operational but has not notified an operator of its closure.

Status *Unknown: Not Currently Participating* indicates a pharmacy that is not currently reporting data to Rx Open (all US-based national chains are participating pharmacies). Non-participating pharmacies also include those pharmacies that have opted out of status reporting.

Following the reporting period, all pharmacy status data was exported for analysis. This was used to calculate the overall percentage of participating pharmacies reporting a status of *Open* (open rate) as well as the change in open rates over time (recovery rate) of pharmacy operations following both Hurricanes Irma and Maria.

Open rate of pharmacies was calculated by dividing pharmacies reporting *Open* by the sum of pharmacies reporting *Open*, *Closed*, and *Unknown*. Pharmacies reporting *Status Unknown: Not Currently Participating* were excluded from the analysis. Daily recovery rate was calculated by subtracting the open rate for a given date from the open rate of the previous date.

To compare open rates of pharmacy operations over time in different contexts, Rx Open data for the state of Florida was analyzed during the same 2017 hurricane season for Hurricane Irma. Florida was chosen as a suitable point of comparison because, like Puerto Rico, the entire state of Florida was declared to be in a state of emergency preceding the landfall of Hurricane Irma.[18] Florida's open rates and recovery rates were determined using the same methodology as described above for Puerto Rico for September 8, 2017 through October 12, 2017.

We also calculated the time (in terms of days after landfall) it took pharmacy operations in Florida and Puerto Rico to reach open rate benchmarks. Benchmarks were calculated for Hurricanes Irma and Maria in Puerto Rico and Hurricane Irma in Florida. Open rate benchmarks between 15.0% and 95.0% were set in increments of 5.0%. We used Excel Lookup functions to determine the first date open rate was greater than or equal to each benchmark and recorded the number of days after landfall that corresponded to that date. The Lookup function was applied to open rates for each event beginning with the minimum open rate after landfall for that event.

RESULTS

From September 5, 2017 to November 10, 2017, approximately 70.0% of the 1045 pharmacies in Puerto Rico and 78.0% of the 4855 pharmacies in Florida were participating in Rx Open and were included for analysis.

FIGURE 1

Pharmacy open rate in Puerto Rico from September 5, 2017 to November 10, 2017. Decreases in pharmacy operation (open rate) can be seen in the days following Hurricane Irma's landfall (September 6) and Hurricane Maria's landfall (September 20), with the fall in open rate following Hurricane Maria being particularly steep.
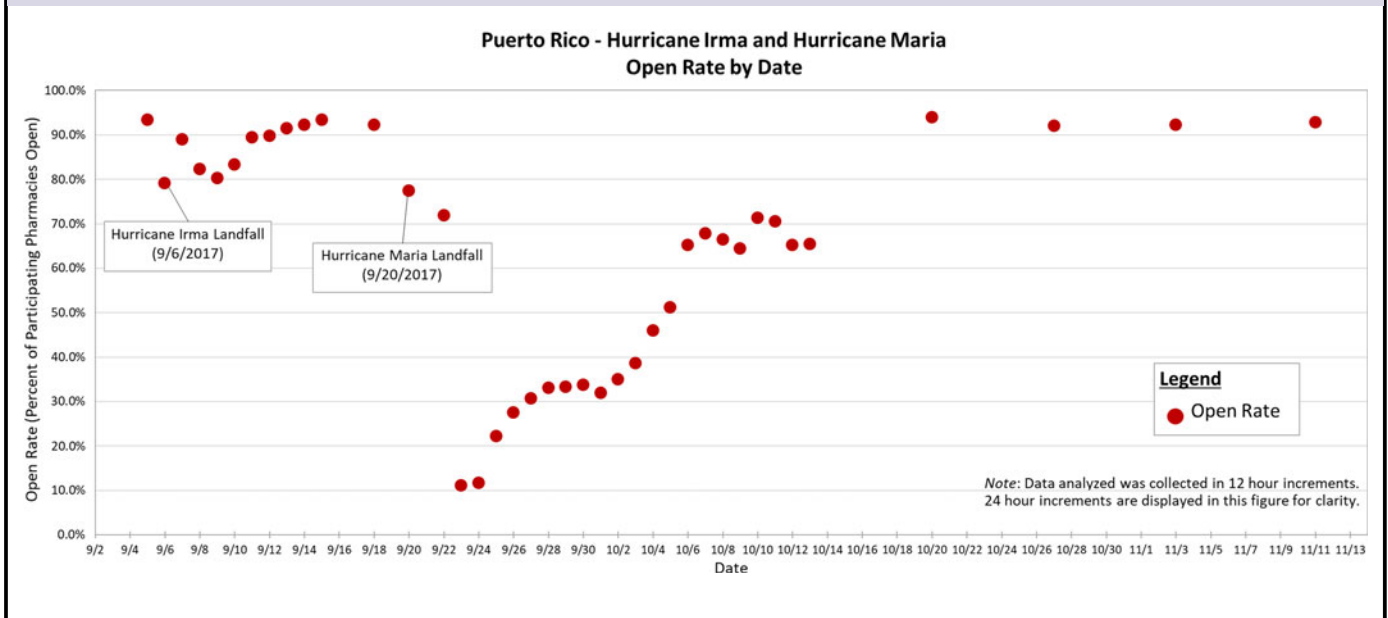
Puerto Rico - Hurricanes Irma and Maria Pharmacy Status and Recovery

The first data point for analysis occurred at 21:19 Atlantic Standard Time (AST) on September 5, 2017. At this time, 626 of the 670 participating pharmacies in Puerto Rico were reporting open status (93.4%). This open rate of 93.4% is the baseline for pharmacy status before Hurricane Irma passed north of Puerto Rico at 6:00 AST on September 6 (Figure 1).

The next open rate recorded occurred at 21:19 AST on September 6, approximately 1 hour after Hurricane Irma passed the northern coast of Puerto Rico. The open rate at this time fell to 79.1%, the lowest open rate for the reporting period prior to the date Hurricane Maria made landfall (Figure 1). The open rate increased to 89.0% on September 7 before falling to 82.3% and then 80.3% on September 8 and 9, respectively (Figure 1). In the following days, the open rate increased incrementally before reaching pre-Hurricane Irma baseline level on September 15, 2017 (Figure 1). The average daily recovery rate from September 9 to September 15 was 2.2%. Between September 5 to September 15, 2017, the maximum daily recovery rate was 9.9% (between September 6 and 7); the largest decrease in open rate for this time span was 14.3% (between September 5 and 6) in the immediate aftermath of Hurricane Irma (Figure 1).

On September 18, 2017, 12 days after Hurricane Irma glanced Puerto Rico and 2 days before Hurricane Maria made direct landfall on the island on September 20, the open rate was 92.3% (Figure 1). The open rate recorded for September 20 was 77.4% while the first available data for analysis following landfall was on September 22, at which point the open rate was 71.8%. The lowest recorded open rate for pharmacies (11%) occurred 1 day later (Figure 1). From this point, recovery rates (and thus, open rates) trended primarily upward; the average recovery rate from September 23 to November 10 (minimum open rate to baseline) was 3.9%.

From September 18 to November 10, the largest decrease in open rate was 60.7% (between September 22 and 23); the maximum daily recovery rate was 14.1% (between October 5 and 6).

Puerto Rico - Hurricane Maria and Florida - Hurricane Irma

On September 8, 2017 at 14:29 EDT, 2 days before Hurricane Irma's landfall in Cudjoe Key in Southern Florida, 3424 of the state's 3690 participating pharmacies were reporting open status (92.8%). On the evening of Irma's landfall on September 10 in Florida, the open rate was 72.3% (Figure 2). The minimum open rate for Florida pharmacies after Hurricane Irma was 39.3% and occurred 1 day after landfall (Figure 2). The minimum open rate for Puerto Rico pharmacies after Hurricane Maria was 11.1% and occurred 3 days after landfall (Figure 2).

The open rate for Florida pharmacies after Hurricane Irma did not fall below 35%. The minimum open rate (39.3%) occurred approximately 12 hours after Hurricane Irma's landfall

FIGURE 2

Comparison of pharmacy open rate following Hurricane Maria in Puerto Rico and following Hurricane Irma in Florida.
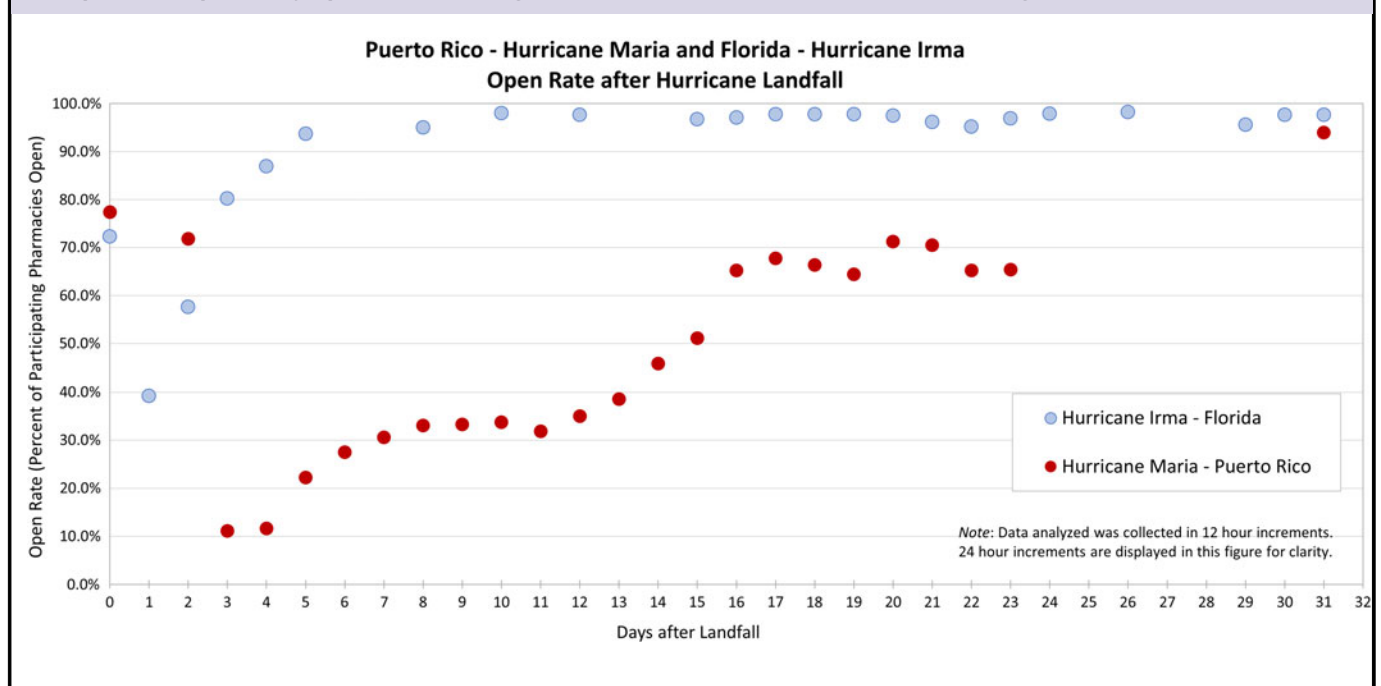
(Figure 2). Florida pharmacies reached the 40.0% open rate benchmark 1 day after Irma made landfall in the state (Table 1). Florida's open rate continued to exceed multiple benchmarks each day (Table 1). In a week after landfall, Florida's open rate reached 95%. The average daily recovery rate from September 11 to 15 (minimum open rate to baseline) was 13.6%. The rise in open rate for Puerto Rico pharmacies after Hurricane Maria was much slower, with multiple days passing between each benchmark decile.

DISCUSSION

The results presented mark the first time data from Rx Open has been formally utilized to describe pharmacy operations after a disaster triggered by natural hazards. The platform's coverage of 70.0% of all pharmacies in Puerto Rico and 78.0% of all pharmacies in Florida provides a unique opportunity to investigate the magnitude of pharmacy closures in the areas affected by Hurricanes Irma and Maria.

Hurricane Irma led to widespread disruption of electricity, water, and telecommunications in Puerto Rico.[1] The disruption to pharmacy operations caused by this hurricane are evident by the drop in open rate following the storm. The relatively rapid return to baseline open rate in Puerto Rico after Hurricane Irma, which took just over 1 week, indicates Puerto Rico's ability to weather and quickly recover from a storm that did not fully sever infrastructure (Figure 1). Although the state of Florida was impacted more severely by Hurricane Irma, the average daily recovery rate from minimum

open rate to baseline following Irma was significantly faster for Florida (13.6%) than for Puerto Rico (3.9%). Although a significant statewide impact on pharmacy operations was observed in Florida (lowest open rate of 39% 1 day after landfall), a return to baseline was observed in less than 1 week (Table 1).

The results from Hurricane Maria, however, demonstrate the unique severity of the disaster's impacts on Puerto Rico's critical healthcare infrastructure. With an absolute drop in baseline open rate of 82.3%, and much longer delays in restoring pharmacy operations compared to Hurricane Irma (Figure 1), these results are consistent with reports of patients having difficulty accessing their medications in Puerto Rico following Hurricane Maria.[12,15] This prolonged recovery in Puerto Rico is particularly striking when compared to the recovery in Florida from a storm of comparable magnitude and geographic distribution, but also reflective of the policy and infrastructure investments made to bolster healthcare resilience in the state (Figure 2). On average, Florida reached open rate benchmarks 10 times more quickly than Puerto Rico (Table 1). Furthermore, Florida's open rate after Hurricane Irma did not fall below 35.0%, while Puerto Rico's open rate after Hurricane Maria dropped to 11.1% (Table 1), which illustrates the degree to which the entire territory and its healthcare system were impacted by Hurricane Maria. While determining the reason for differing rates of recovery between Florida and Puerto Rico is beyond the scope of this analysis, we hypothesize that Florida's faster recovery is related to the relative speed of infrastructure recovery, particularly

TABLE 1

Days after Landfall Before Open Pharmacy Benchmark Reached after Major 2017 Hurricane Season Storms in Florida and Puerto Rico

	Days after Landfall Before Open Pharmacy Benchmark Reached		
Open Rate	Florida - Irma	Puerto Rico - Maria	Puerto Rico - Irma
10.0%			
20.0%		5.0	
30.0%		7.0	
40.0%	1.0	13.5	
50.0%	1.5	15.0	
60.0%	2.0	16.5	
70.0%	2.0	20.5	
80.0%	2.5	30.0	2.5
90.0%	4.5	30.0	5.0

power. In Florida, power was restored to over 90% of customers 10 days after Irma's landfall.[19] In Puerto Rico, even 4 months after Maria's landfall, power was restored to only 65% of the island.

It is noteworthy that the lowest open rate of pharmacies in Puerto Rico did not occur until 3 days following Hurricane Maria's landfall. Data from September 22, 2 days after landfall showed many pharmacies (71.8%) reporting open status prior to the ultimate drop to the absolute low of 11.1% the following day. Staffing constraints, generator fuel shortages, and resupply challenges may have been cumulative factors that strained healthcare operations after the event and ultimately contributed to the delayed drop to 11.1% days after Hurricane Maria's landfall.

This study has several limitations:
(1) Although Rx Open provides coverage of 95% of pharmacies nationwide, the coverage in both Puerto Rico and Florida is somewhat lower due to lower participation from independent community pharmacies in certain regions of those jurisdictions. Nonetheless, with coverage in these areas from 70-78%, we believe that these results are demonstrative of the trends in pharmacy operations during the 2017 hurricane season. (2) There were dates where data was unavailable for analysis due to infrastructure impacts and a change to once weekly updates after October 13 which was instituted due to the slow rate of recovery. Still, we believe the available data provides a clear picture of pharmacy status in the affected areas.

Despite the magnitude of the events of the 2017 hurricane season, there is still a need for further research to examine the multi-level factors that strained the healthcare system.[20] Such research is needed to better inform public policy and effective disaster planning. To improve the understanding of the impact the 2017 hurricane season had on pharmacies and healthcare more broadly, additional analyses should be conducted for other types of infrastructure crucial to healthcare systems as well as other geographic areas that were impacted. Analysis of pharmacy status data in the US Virgin Islands, Texas, and other areas affected during the 2017 hurricane season will be reported in future correspondence, and will contribute to a more holistic picture of the critical infrastructure healthcare impact on the US during major disasters.

CONCLUSION

Hurricane Maria brought unprecedented challenges to pharmacy operations in Puerto Rico that lasted for months following the natural disaster. In addition to helping patients get access to medicine in an emergency disaster-stricken area, Rx Open provides a unique opportunity to better understand how these natural disasters affect pharmacy operations and recovery. By better describing the impact of disaster pharmacy operations, and the link to patient outcomes after a disaster, we hope additional consideration of the critical role of pharmacies and pharmacists in disaster response will be explored, as well as strategies to increase their resilience in the face of future events.

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Author Contributions

All authors (CER, KM, KYH, SMB, and NAL) contributed to the conception and strategic design of the study. CER, KYH, SMB, and NAL collected data for the study. CER and KM performed data analysis and interpretation. The article was drafted by CER and KM as co-first authors, and critical revision and approval was performed by all authors.

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