Paramedic Life Threatening Medical Emergencies Mirror COVID-19 Hospitalization Trends in 2020: Exposing the Toronto Neighbourhood Gap

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Abstract

Through exploratory data analysis (EDA) on the Paramedic Medical Incidents 2010-2020 dataset, and the COVID-19 Case Numbers dataset from Open Data Toronto, this study shows that while 2020 had less overall medical emergencies than 2019, it had more occurances of life threatening respiratory/cardiac (Echo-level) incidents. Plotting a line graph comparing the Echo incident trend with the COVID-19 hospitalization curve reveals a similar trajectory: A peak in April, followed by a steady Summer before escalating again in the Winter starting in October. In addition, through creating heatmaps of paramedic Echo-incidents in 2020 and 2019, along with COVID-19 hospitlizations in 2020, the study shows that there are interesting overlaps among Toronto neighbourhoods, with North-Western Etobicoke (Jane and Finch) for example that exhibits high risk in both COVID-19 hospitalizations and Echo-incidents. Ultimately the results hope to inform future research into examining the relationship between Echo-incidents and COVID-19, and look at why certain neighbourhoods are at a higher risk of being hospitalized for COVID than others.

Contents

1 Introduction

The deadliness of COVID-19 has been swamped with misinformation and confusion. To make sense of how the pandemic has been impacting the Metropolitan Toronto Area specifically, this project asks whether there had been an increase in life-threatening respiratory or cardiac emergencies within the region during 2020. Drawing upon the Paramedic Services Incident Data 2010-2020 and the COVID-19 Cases in Toronto datasets from Toronto's Open Data Catalogue, this project firstly draws comparisons between medical emergencies in 2020 and the past 11 years, then proceeds to compare the trend of 2020 medical emergencies with COVID-19 hospitalization trends. Lastly, 2 heatmaps were created to investigate whether the regions with high medical emergencies coincided with areas that had more COVID-19 hospitalizations, creating potential for future research.

The results were telling. While it was surprising that 2020 actually reported less overall medical emergencies (of all severity) than 2019, once the data was filtered down to the Echo-level (life-threatening respiratory or cardiac) emergencies in 2020, and then compared to the COVID-19 hospitalization line, it is apparent that both trends mimic each other, and COVID-19's overall epidemic curve in general: **Rise to a peak in April, stabilize during the Summer, and then spiking in October before remaining high in the Winter.** A cross-reference with news articles and data from the Ontario Ministry of Health adds further support. When both paramedic and COVID data was geomapped onto Statistics Canada's 2016 Census Boundary Forward Sortation Area file, the results showed significant overlap in neighbourhoods both having issues with higher numbers of Echo-level incidents and COVID-19 hospitalizations.

The issue regarding these results is that they require diving into a degree granularity before the serious impacts of COVID-19 can be gleaned. As the heatmaps will show, there are significant large portions of "low-risk" neighbourhoods that skew the overall picture. Indeed, for most neighbourhoods, the lockdown has indeed led to 2020 having less overall medical emergencies compared to 2019. However, for select neighbourhoods, the data shows a completely different story, and opens up opportunities for policy makers to dive in. The project can be accessed on Github.[1]

2 Methods

All of the analysis was done using R (R Core Team 2020). Datasets were downloaded using the Toronto Open Data Package (Gelfand 2020), reproducible file paths utilized the here package (Müller 2020), and data cleaning/transformation was done with tidyverse (Wickham et al. 2019).

[1]GitHub repository for study: https://github.com/JeremyJChu/paramedic_incidents

The shapefile was read and manipulated using rgdal and maptools (Bivand, Keitt, and Rowlingson 2021; Bivand and Lewin-Koh 2020), and errors were resolved using rgeos and gpclib (Bivand and Rundel 2020; Duncan Murdoch and Alan Murta 2020). All graphs were plot and arranged using a combination of ggplot2, gridExtra, and gghighlight (Wickham 2016; Auguie 2017; Yutani 2020). Tables were created using knitr::kable (Xie 2014) and kableExtra (Zhu 2020). The creation of the final product was aided with ggpubr, knitr, bookdown and magick (Kassambara 2020; Xie 2014, 2016; Ooms 2021).

3 Data

3.1 Source

3.1.1 Paramedic Services Incident Data 2010-2020 (Open Data Toronto)

Published by Toronto Paramedic Services, the dataset contains information on the emergency dispatch responses from Toronto Paramedic Services between the years 2010-2020. Incident data is obtained whenever a valid 9-1-1 emergency call is dialed in and logs up to the point in which Paramedic Services have been dispatched. There is no information on the outcome of the emergency. Data is refreshed annually (Toronto Paramedic Services 2020).

3.1.2 COVID-19 Cases in Toronto (Open Data Toronto)

Published by Toronto Public Health, the dataset is the most up-to-date source of COVID-19 cases within Toronto. Case data is obtained whenever a COVID-19 case is reported directly from laboratories to public health department, and after thorough investigation by Toronto Public Health, the data is summarized to show trends. It must be stressed that all data is preliminary. Data is updated weekly (Toronto Public Health 2021).

3.1.3 2016 Census – Boundary Files (Statistics Canada)

Published by Statistics Canada for public usage, this project will utilize the Forward Sortation Area shapefile in English from Statistics Canada's 2016 Census – Boundary Files (Statistics Canada 2019). The shapefile contains Canada-wide boundary information based on forward sortation area codes - the first 3 characters of the Canadian postal code. For more information on FSAs, please see Office of the Superintendent of Bankruptcy Canada (2015).

3.2 Metadata

3.2.1 Paramedic Services Incident Data 2010-2020

The dataset contains 6 fields, for the project the following 4 will be examined:

Dispatch_Time: When paramedic services were dispatched. Format ISO 8601.

Incident_Type: Type of incident. Medical, Motor Vehicle Accident, Emergency Transfer, Fire, or Airport Standby.

Priority_Number: Priority of incident: 1, 3, 4, 5, 9, 11, 13, 12. See section: Understanding and Acknowledging Bias below for more information.

Forward_Sortation_Area: General location of incident according to the FSA code.

For more detailed metadata, please consult Raftis and Pacholok (2013).

3.2.2 COVID-19 Cases in Toronto

The dataset contains 18 fields, for the project the following 3 will be examined:

FSA: Forward sortation area of where the COVID-19 case was reported.

Reported Date: The date when public health units become aware of the case. Chosen over `Episode Date` because some are estimates and the purpose of the project is to look at cases serious enough to warrant hospitalization.

Ever Hospitalized: Boolean field, data is filtered for Yes to only show cases that were hospitalized.

3.3 Understanding and Acknowledging Bias

3.3.1 Paramedic Services Incident Data 2010-2020

The point of contention is what determines priority. The priority number is determined by Toronto Paramedic Services based on the Medical Priority Dispatch System (MPDS). The MPDS is a system in which once a caller dials 9-1-1 to report an emergency, the telecommunicator at the Dispatch Centre poses a series of scripted questions and triages the answers into pre-established MPDS codes (See Table 1. Created using knitr::kable and kableExtra (Xie 2014; Zhu 2020)). Those codes and then turned into the priority numbers in the dataset ("Paramedic Services Incident Data Description," n.d.; Raftis and Pacholok 2013).

Table 1: Medical Dispatch Priority System Reference Table

Priority Number	Priority Code	Priority Definition
9	Echo	Life Threatening, Cardiac/Respiratory Arrest
1	Delta	Life Threatening, not Cardiac/Respiratory Arrest
3	Charlie	Serious, not Life Threatening
4	Bravo	Non Serious/Non Life Threatening, Treatment Required
5	Alpha	Non Serious/Non Life Threatening, Minimal Intervention
11	Alpha1	Non Serious/Non Life Threatening, Minimal Intervention
12	Alpha2	Non Serious/Non Life Threatening, Minimal Intervention
13	Alpha3	Non Serious/Non Life Threatening, Minimal Intervention

Despite the efficiency and effectiveness of this system in standardizing responses to 9-1-1 calls, allowing for quick allocation of limited resources, there are some caveats that must be kept in mind when analyzing paramedic incident data from a statistical and ethical perspective.

Accuracy of MDPS

According to Bohm and Kurland (2018), the current state of MDPS lacks both a consensus on "common standards for reporting" and subsequently any measure of accuracy for the MDPS reporting system. In other words, Bohm and Kurland (2018) have found evidence of over-triage and under-traige of incidents. That is, excessive or insufficient responses for the incident at hand. Of course, this is not a critique of the medical system. The MDPS leans toward over-triage and with good reason, it is afterall better safe than sorry. However, evidence of under-triage is problematic, and even more troublesome is the complete lack of accuracy evaluation. This makes it difficult to determine which cases were over, under, and accurate triage from just the data.

Codification of Emergencies

Despite its good intentions, it is important to note that the data presented in the paramedic incidents dataset is first only a subsection of the priority codes, as there are a plethora of subcodes that give further detail to the type of incident (ie. 12-D-2 implies continuous or multiple seizures) (Clawson and Dernocoeur 2001). The priority codes are nothing but the highest level of categorization, and will conflate different types of incidents (various medical, fire, traffic) into the same number code. Ultimately, this limits the extent of insights that can be gleaned from a standalone dataset.

3.3.2 COVID-19 Dataset

Statistically, bear in mind that the Reported Date field is subject to human error. Delayed reporting is a risk. Even for patients who get hospitalized over COVID, their report date could be days prior to hospitalization. Understand that there will be malleability in time.

4 Analysis

4.1 2020 Had Less Medical Overall Emergencies Than 2019, but More Life Threatening Emergencies

Keeping in mind the potential pitfalls of the datasets, let's explore the data. Using tidyverse (Wickham et al. 2019), I first filtered the dataset to show only medical emergencies, and subsequently created a bar chart comparing 2019 to 2020 using ggplot2 (Wickham 2016) (See Figure 1). Between 2020 and 2019, surprisingly 2019 actually had more total emergency calls and dispatches than 2020.

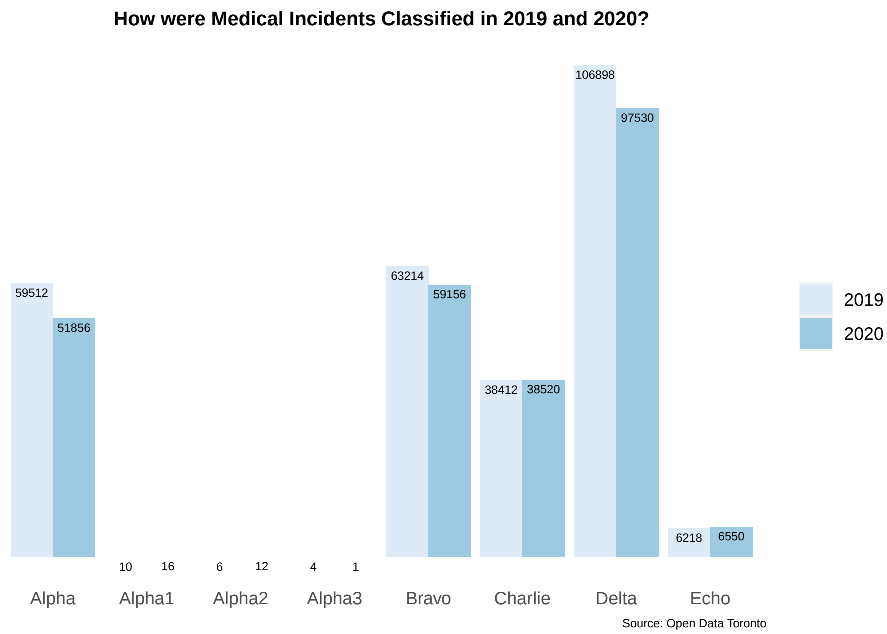

Figure 1: Medical Bar

Only Charlie and Echo-levels reported more incidents in 2020. At first glance, the difference seems minuscule. However, I was less concerned about the number, but rather when the incidents occurred. It is also important to find out whether 2020 showed a different trend compared to previous years. Filtering only Echo-level incidents with tidyverse because of its cardiac and respiratory category and therefore attribution to COVID-19 (Wickham et al. 2019), I compared the Echo incident trends between 2019 and 2020 and plotted a line graph with ggplot2 (Wickham 2016) (See Figure 2).

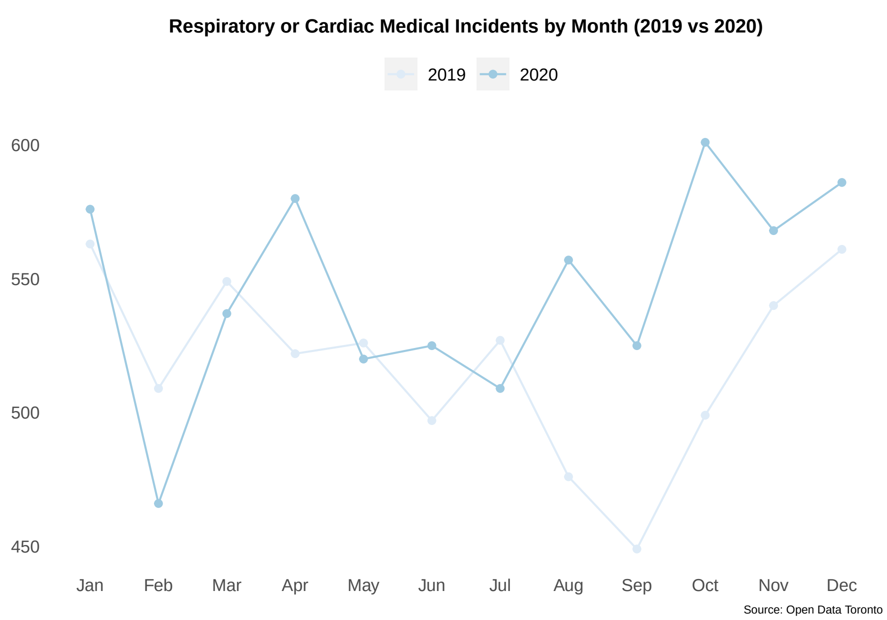

Figure 2: 2019 vs 2020 Echo Incidents over Time

Compared to 2019, 2020 saw incident peaks in **April**, **August**, and **October**. Incidents start trending up from February before hitting a peak in April, they proceed to remain constant during the Summer before rising again in the Winter.

4.2 2020 Echo Incidents Trend is Similar to COVID-19 Epidemic Curve

Taking a look at the COVID-19 epidemic curve from the Ministry of Health (Ontario Ministry of Health 2021):

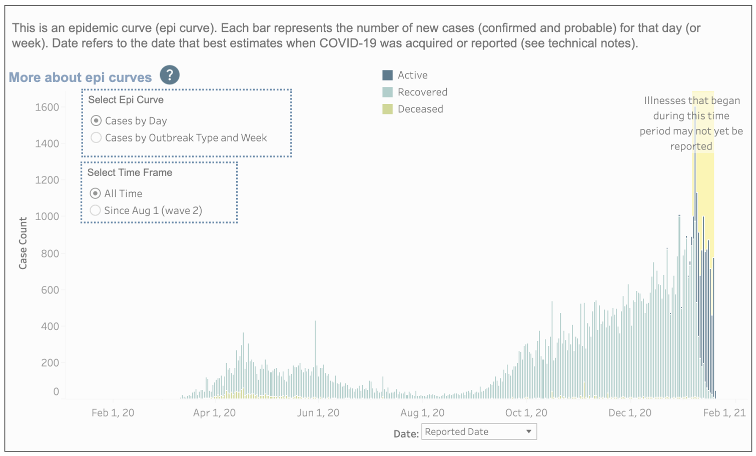

Figure 3: Ministry of Health Epidemic Curve

CP24 (Fox 2020) reported 550 (51.8% GTA) new COVID cases in early April, with cases fluctuating until the Summer months when the first lockdown reigned cases in, showing continuous weeks of low cases (Davidson 2020). What differs is that although cases only started rising in October and persisted into the Winter, Echo incidents showed an interesting increase in August. However, Echo incidents likewise saw a sharp spike to beyond April levels in October and remained high till the end of 2020.

The question remains as to whether the 2020 Echo incident trend is special or not. Could other years report similar increase in incidents during Winter because of the cold weather? In addtion, as we are looking at paramedic data, it is also important to know whether COVID-19 hospitalizations follow a similar trend.

4.3 2020 is a Special Year After All!

I took all the sheets (2010-2020) from the paramedic incidents dataset, cleaned, merged, and filtered them all using tidyverse (Wickham et al. 2019), and plotted with ggplot2 (Wickham 2016), with the gghighlight package responsible for the highlighting of 2020 (Yutani 2020) (See Figure 4).

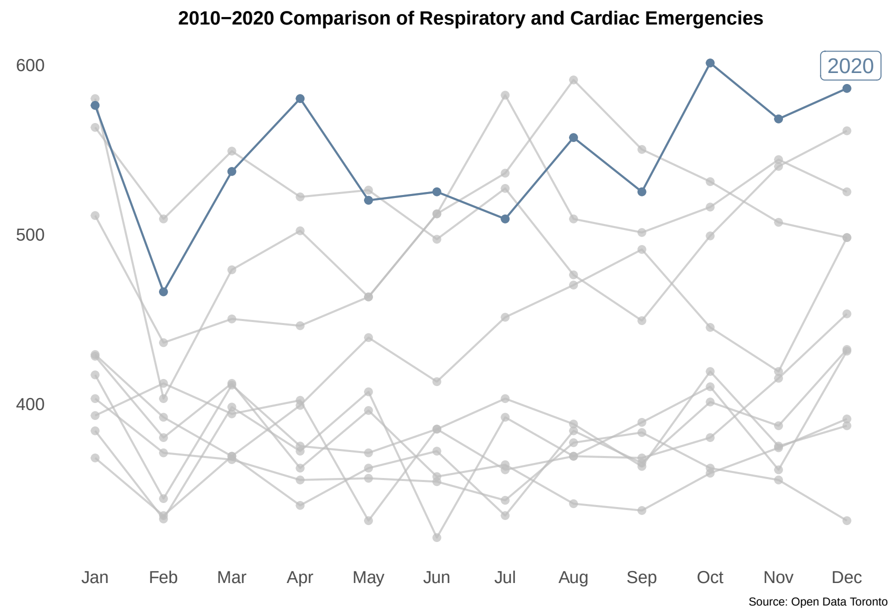

Figure 4: 11 Years of Respiratory/Cardiac Emergencies

Comparing data across 11 years, the answer seems to be yes, 2020 is indeed special. Not only do cases trend generally higher than other years, the April and October peaks are the highest in 11 years. Moreover, the 2020 trend does not bear any similarities to other years, with some years dipping in incidents during the Winter instead. When we compare the trends between Echo incidents and COVID hospitalizations, unsurprisingly the line follows the overall COVID epidemic curve as well (See Figure 5) (Plotted with ggplot (Wickham 2016) and grid.Arrange (Auguie 2017)). This means that we are seeing increased Echo-incidents and COVID hospitalizations in the same month, opening up further opportunities for research.

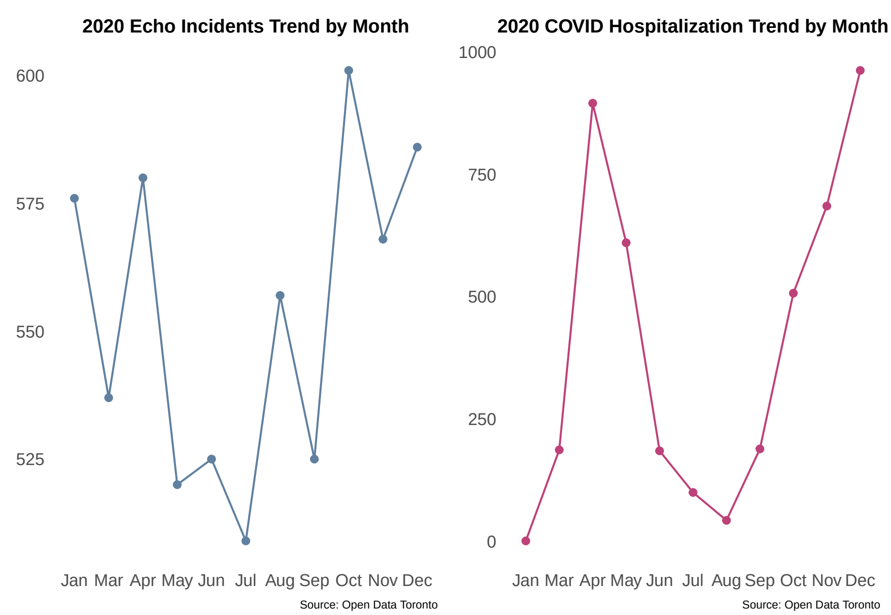

Figure 5: 2020 Echo Incidents vs COVID cases

Please note that the y-axis scale is different, the figure above is only meant to show the similarities in trends.

4.4 Toronto Neighbourhoods' Uneven Distribution of Risk

It would be a shame to end the project without looking at possible region similarities (or difference) between Echo incidents and COVID hospitalizations in Metropolitan Toronto. After downloading a shapefile from Statistics Canada from the 2016 Census and filtering for only 'M' FSA codes (covers Metropolitan Toronto) using rgdal (Bivand, Keitt, and Rowlingson 2021), I merged the shapefile with both the Paramedic Incidents and COVID-19 dataset, and created heatmaps of case/incident numbers using ggplot2 (Wickham 2016), merged with the gridExtra package (Auguie 2017) (See Figure 6).

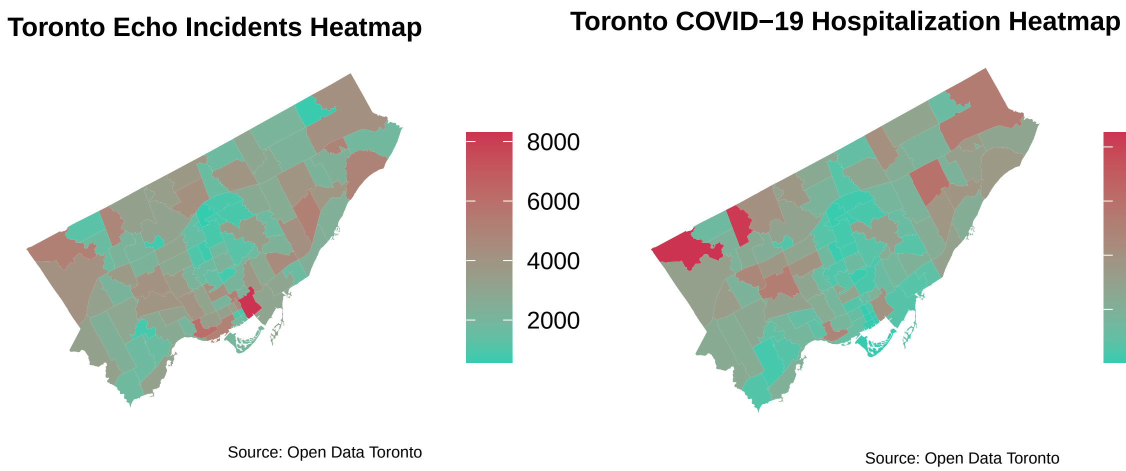

Figure 6: Toronto Heatmap (2020): Echo vs COVID

First thing to note is that once again the scale is different, there are vastly more Echo incidents than COVID cases that resulted in hospitalizations in 2020. Scale aside, the red portions of the map eerily overlap. On the top-left of Toronto, upper Etobicoke - the Etobicoke General Hospital and Jane and Finch areas show the highest number of COVID hospitalizations; similarly the two areas are ranked 4th and 9th highest for Echo incidents in 2020 (See Tables 2, 3). The question for future research becomes what makes three fifths of the top Echo-incident neighbourhoods also be at a higher risk from COVID-19 emergencies and what makes others not?

Lastly, it is important to consider if COVID-19 caused those neighbourhoods to have high Echo incidents, I generated a heatmap of Echo incidents in 2019 as well (See Figure 7). The areas with red show no noticeable difference compared to 2020, which means that the neighbourhoods were already predisposed to medical emergencies.

Table 2: Top 10 Highest COVID Hospitalization Toronto Neighbourhoods

Forward Sortation Area	COVID Hospitalizations
M9V	213
M3N	208
M1P	146
M1B	132
M6M	130
M6K	119
M9N	116
M1W	103
M3J	101

[a] Neighbourhoods also in the top 10 Echo table are highlighted in blue

Table 3: Top 10 Highest Echo Incidents Toronto Neighbourhoods

Forward Sortation Area	Echo Incidents
M5A	8292
M6K	6092
M4Y	5244
M9V	5113
M1K	5107
M5V	5016
M1E	4955
M3N	4778
M4C	4496
M5B	4335

[a] Neighbourhoods also in the top 10 COVID table are highlighted in red

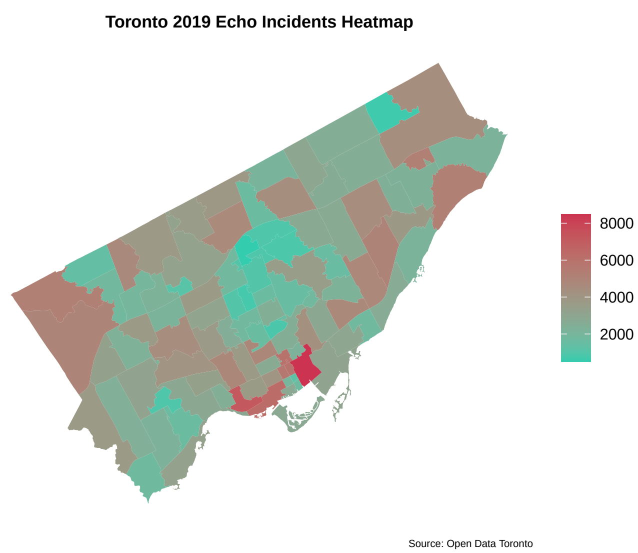

Figure 7: Toronto Echo Heatmap (2019)

5 Moving Forward

The results have demonstrated that there are select neighbourhoods that are just generally higher risk. What this project has shown is where these neighbourhoods are, and that looking at the trend of monthly incidents, with Echo-level incidents mirroring the COVID-19 hospitalization line, that it is likely that those same neighbourhoods are hit harder by the pandemic. It would be interesting for further research to drill down into what makes these regions different, be it income, demographic, or something else. As the heatmaps show, there is a consistent and significant difference between 1/3 of Toronto and the rest of the area.

6 Limitations

As mentioned, the data provided isn't fully reliable. Reported Date of COVID-19 cases is never a true representation of when cases happen, the study's hopes that the aggregation of cases into months helps mitigate some of the unreliability. The priority number of the pandemic incidents must also be kept in mind to be an high level summarization of a pre-determined coding system that is ultimately arbitrarily determined to cover most scenarios but not all. Moreover, the MDPS system leans towards over-triage, therefore a portion of Echo-level incidents will likely be miscategorized. These biases and limitations must be kept in mind when looking at the results and moving forward.

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