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Heat maps for surveillance and prevention of COVID-19 spread in nursing homes and assisted living facilities

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COVID-19 has created unique challenges for societies and healthcare organizations globally. The pandemic has placed our elders at a formidable risk since age is the most significant risk factor for severe morbidity and mortality[1-4]. Consequently, some of the most challenging situations occur in nursing homes (NHs) and assisted living facilities considered hotspots for COVID-19.

In Israel, NHs and assisted living facilities were some of the hardest hit by COVID-19[5]. Henceforth, a national task force appointed by the Israeli Prime minister named "Shield of Fathers and Mothers", was appointed.

In order to aid the task force, we devised a novel, interactive, real-time, dashboard-based heat map tool based on COVID-19 outbreak analytic metrics as well as spatiotemporal data analytics (http://covid19maps.org/). We developed a novel platform, focused on assisted living facilities and NHs, providing the Israeli Ministry of Health (MOH) policymakers with a national graphical representation of all institutes (passkey protected to secure privacy issues). A basic layer, allows to identify all facilities with diagnosed cases (resident or staff) by rendering them as "warm" (red color) if a positive COVID-19 case was identified within an interactive last n days (e.g. last 14 days as a default for the system) or "cold" (blue color) displayed in Figure 1A. Importantly, in addition to basic layer that allow to represent the quantity of the diagnosed cases (displayed as circle-size in the current platform), a key novelty of the developed platform is the ability to follow and intuitively display the trajectories within the facilities where cases were identified. The trajectories can be followed by using a set of mathematical analytic algorithms of evaluating the local COVID-19 spread rates based on replication rate (RR), the rate of spread (RoS), as well as the doubling time[6]. NHs with rapidly escalating trajectories are represented by warm colors and those with stable trajectories are represented by cold colors.

The dashboard enables preventing and acting on disease outbreaks in this susceptible population in the following ways:

A picture at a glance to direct efforts - The task force is able to quickly assess the national picture in all of the various nursing and assisted living homes and direct its diagnostic, and therapeutic efforts (Figure 1A).

Outbreak linkage - Outbreaks in NHs and assisted living facilities can be catalyzed by the healthcare staff[7], some of which work in several proximal facilities. The heat map can assist the epidemiologic investigation by allowing an online display of nearby infected facilities thus and linking the outbreak in adjacent facilities to the staff (1B and 1C) thus speeding up the investigation.

Tailoring of disease mitigation steps by heat map layering - Most of the sweeping public health measures endorsed by health policymakers lack in data and are nonselective. The resultant detrimental health implications on the elderly population in these facilities may be severe. The dashboard we developed monitors municipalities as well as the nursing and assisted living facilities. By layering over the two heat maps (figure 1D), policymakers are able to quickly assess whether the facilities are located in "hot" or "cold" municipal zones and are able to make data-driven, precise mitigation steps in the facilities. Moreover, as staff may live in the municipalities around the facilities, this feature enables better risk assessment.

Patient allocation Some of the residents diagnosed with COVID-19 deteriorate, and their admission to a general hospital might be inevitable. The system enables policymakers in deciding where to admit these often-complex patients based on the hospital burden for ventilated and non-ventilated patients using the heat map layer displaying the hospital occupancy burden and trajectories. Optimizing patient allocation will enable the healthcare system to provide better care as the elderly will be directed to hospitals with les burden limiting healthcare contingency.

Channeling messages to leadership and the general public as some of the disease mitigation steps taken in these facilities are consequential for the elderly population[8], the importance of channeling the decisions transparently is of utmost importance. The simple and intuitive heat map display helps deliver a clear reasoning for actions taken.

Policymakers as well as healthcare providers must contain the disease spread as tightly as possible in this susceptible population. We urge countries and healthcare organizations to adopt such tools for data-driven monitoring of outbreaks for the vulnerable population living in nursing homes. Analytical heat maps, beyond standard dashboard based graphic data representation of COVID-19 case quantities, are essential for tracking COVID-19 pandemic dynamics, preventing

institute-based outbreaks, and may be instrumental for devising diagnostic and therapeutic strategies in the high-risk population.

Conflict of interests

All authors have no conflicts of interests regarding the research.

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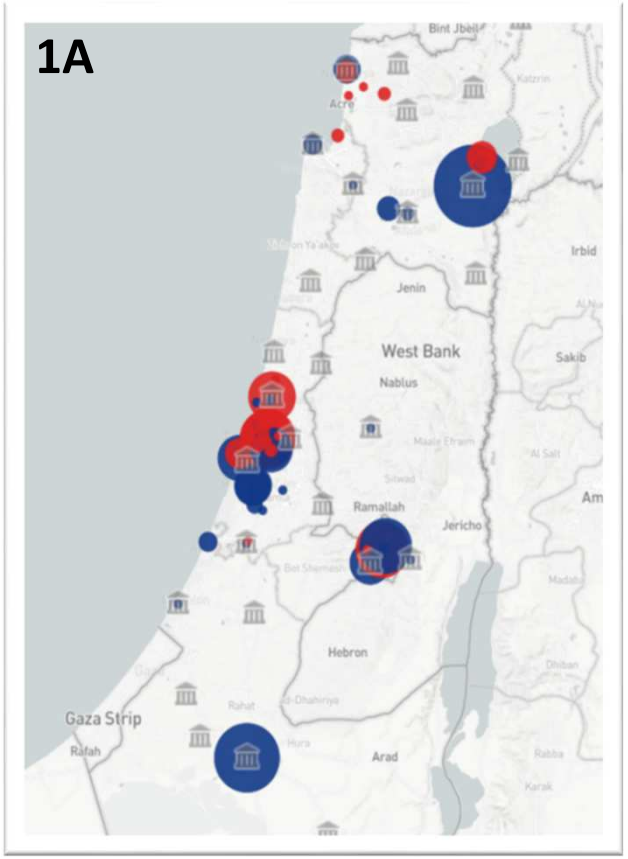
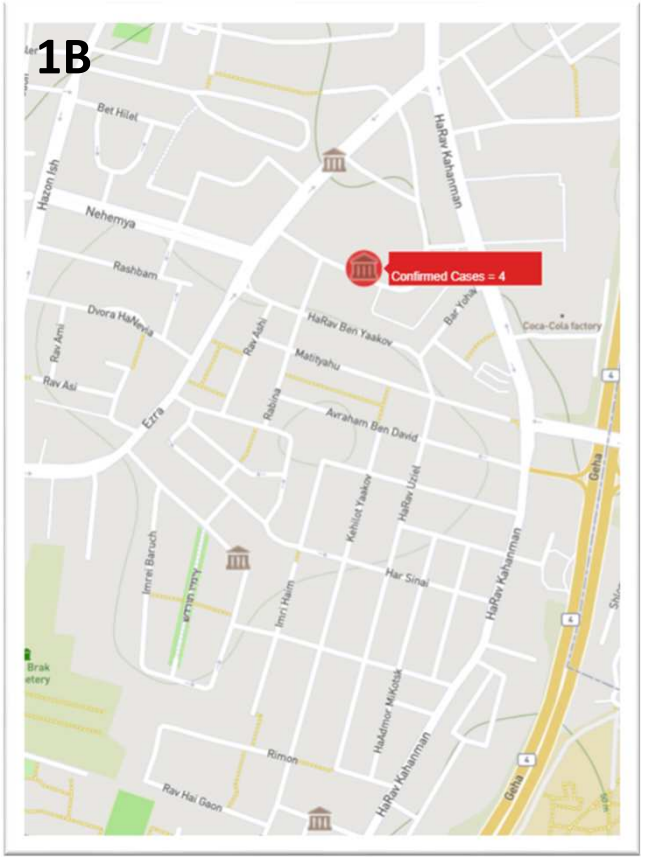
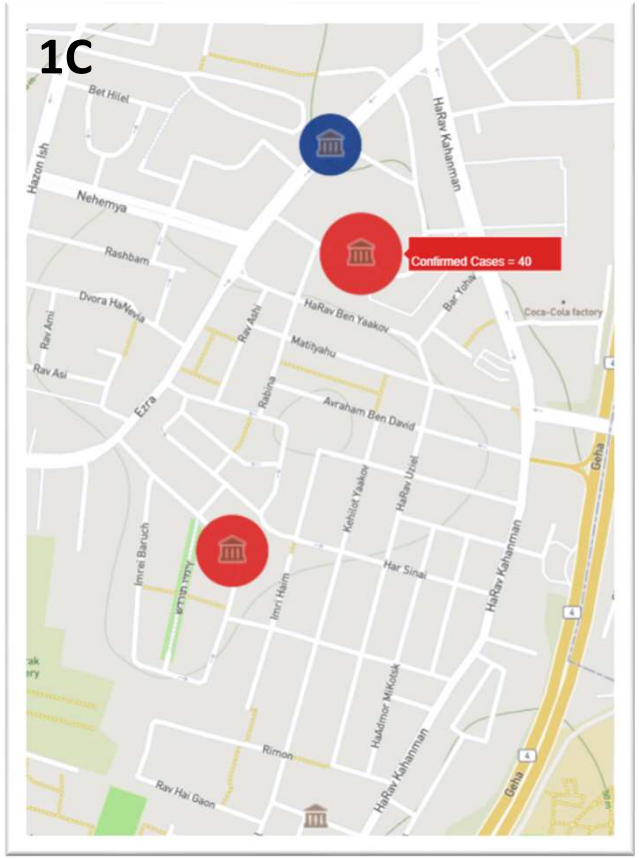
Figure 1 legend

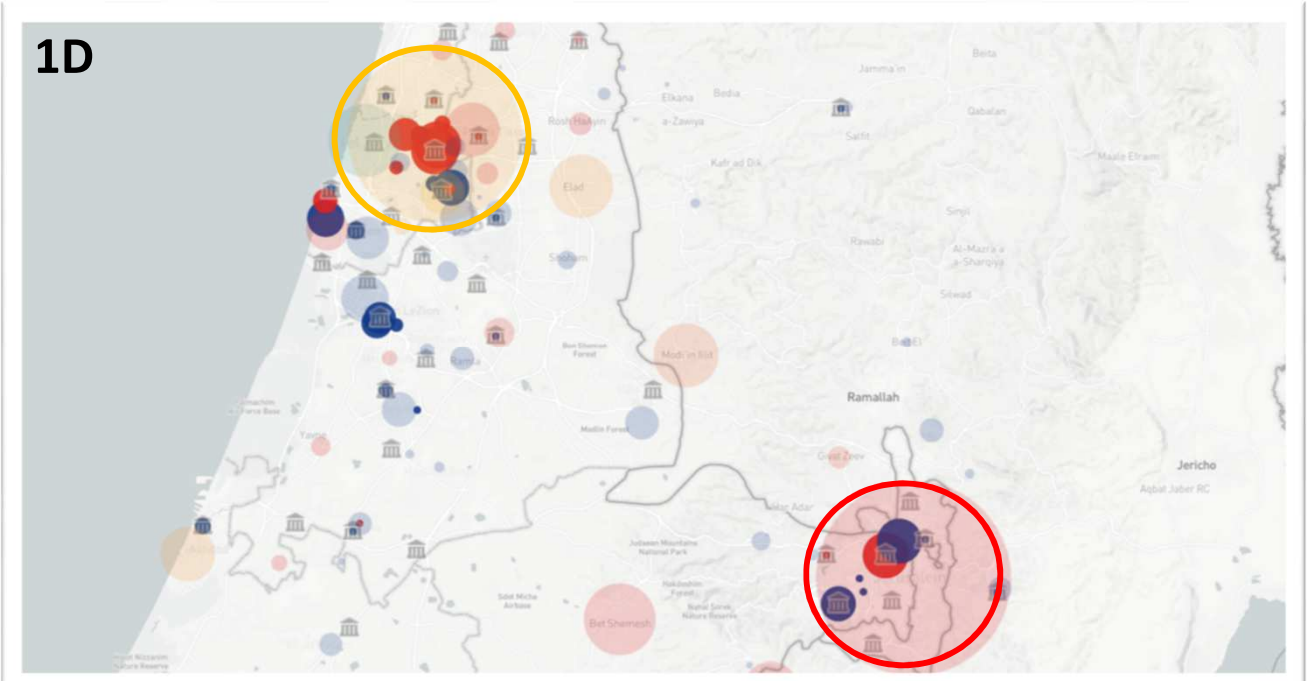
Figure 1: The heat map display of COVID-19 spread in nursing and assisted living facilities in Israel.

The heat map allows policy makers to make informed decisions by displaying vital information in an easily understandable fashion. Figure 1A displays a national picture at a glance, where the red color indicates facilities with a diagnosed case in the past two weeks (blue color indicates the opposite). The circle size indicates the number of cumulative cases. As disease outbreaks in facilities has been linked to staff workers, monitoring facilities (staff, resident or both) adjacent to hot spots assists in directing diagnostic efforts of residents and more importantly joint staff. In the city of Bnei Brak an outbreak in 4 staff members was identified on the 17th of April (1B). On May 10th, a widespread outbreak in residents in the index and three neighboring facilities was identified with a total of 94 diagnosed cases in residents and a total of 12 staff members (1C). Moreover, as the nursing and assisted facilities are a part of their municipalities (staff residence, visitation) layering the municipal heat map over the facilities display aids in a more comprehensive risk assessment. In 1D, the lighter shaded halos represent disease trajectories in the cities of Bnei Brak (upper) and Jerusalem, sites of major disease outbreaks in Israel. Layered over the municipal heat map are the nursing and assisted living facilities located within their boundaries.


1A
West Bank
Nablus
Jenin
Ramallah
Jericho
Hebron
Gaza Strip
Rafah
Arad


1B
Confirmed Cases = 4
Bet Hilel
Nehemya
Rashbam
Dvora HaNevia
HaRav Ben Yaakov
Matityahu
Avraham Ben David
Har Sinai
HaRav Kahanman
Coca-Cola factory
Ezra
Rimon
Rav Hai Gaon


1C
Confirmed Cases = 40
Bet Hilel
Nehemya
Rashbam
Dvora HaNevia
HaRav Ben Yaakov
Matityahu
Avraham Ben David
Har Sinai
HaRav Kahanman
Coca-Cola factory
Ezra
Rimon
Rav Hai Gaon


1D
Ramallah
Jericho

Methodology Appendix

The map displays real time COVID-19 disease spread metrics based on data derived from Johns Hopkins University and Israel ministry of health datasets[1].

We assessed disease spread by two measures: The Replication Rate and the Rate of Spread.

Replication rate (RR) was defined as the slope of the logarithmic curve of the natural logarithm of the number of cases diagnosed in each facility. We calculated the slope of a sliding window of size (dT), where we chose dT=3. Let C_t be the number of validated cases of COVID-19 for each facility at day t.

$$Replication\ Rate = \frac{ln(C_{t+dT}) - ln(C_t)}{dT}.$$

Rate of Spread (RoS) was calculated to provide a long-term trajectory. It is calculated by running a linear regression of ln(Confirmed Cases) on time, and taking RoS to be the slope coefficient of the regression. We used a 7-day sliding window, as in Sajadi et al. [2].

$$(RoS)Rate\ of\ Spread\ (RoS)_{n+7} = slope\ of\ the\ linear\ regression\ on \ln(C_n), \dots, \ln(C_{n+6})$$

The calculation of the RoS was conducted by using a window for regression that does not include any missing values. From the RoS one can estimate the doubling time of cases:

Doubling Time = $\ln(2) * \frac{1}{RoS}$.[3]

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