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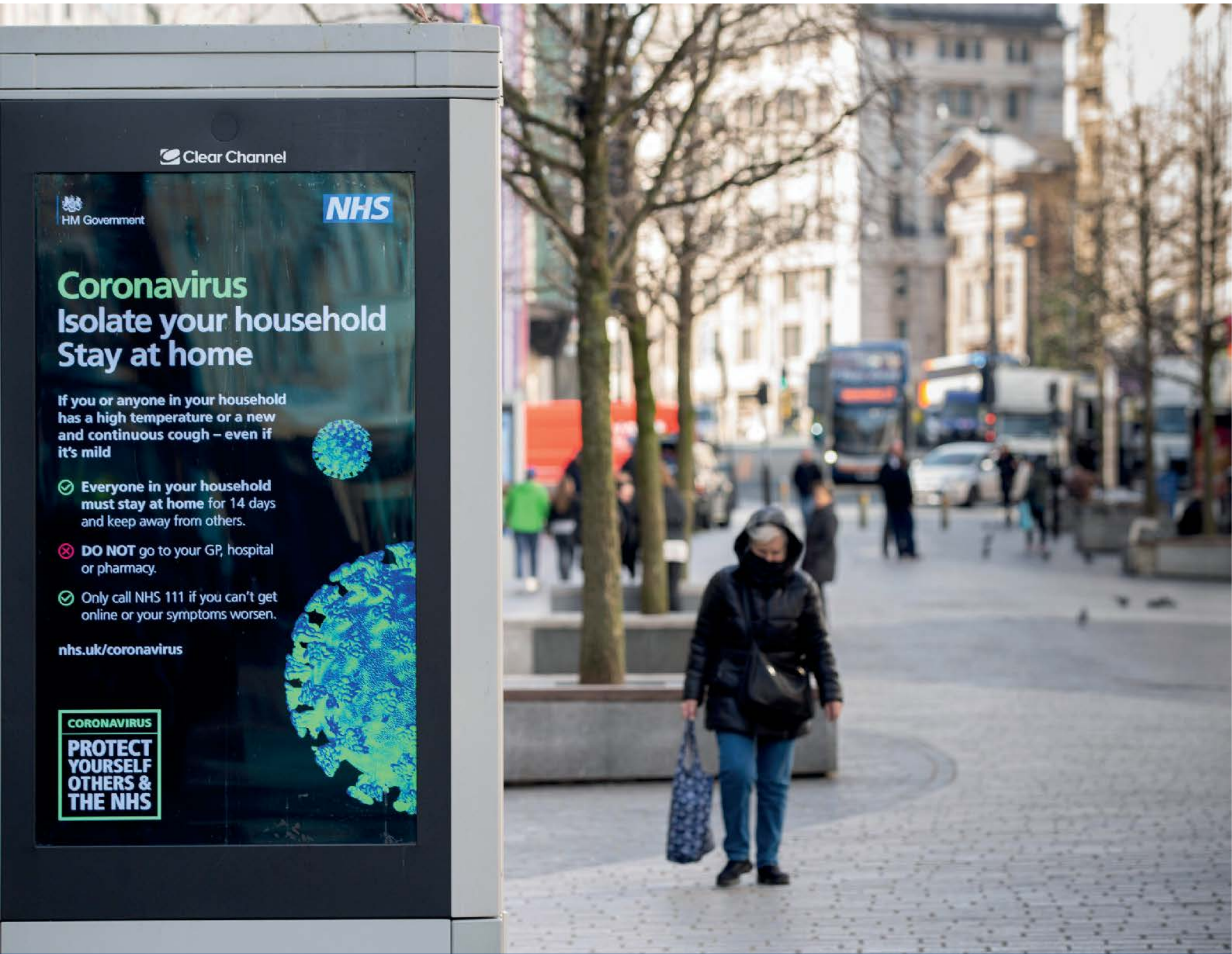

Responding to COVID-19 in the Liverpool City Region

COVID-19: How Modelling is Contributing to the Merseyside Response

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Map of Liverpool City Region Combined Authority (LCRCA) boundary (in red) and constituent local authorities

Data sources: Westminster Parliamentary Constituencies (December 2018 - ONS), Local Authority Districts (December 2018), Boundaries (December 2018 - ONS) and Combined Authorities (December 2018 - ONS)

COVID-19: How Modelling is Contributing to the Merseyside Response

Key takeaways

1. SARS-CoV-2, the virus that causes the COVID-19 illness, is new – there is no pre-existing immunity in populations; it is more infectious than influenza; it can cause a fatal inflammation of the lungs; and there is no vaccine yet.
2. Epidemiological insights on the spread of the virus, including mathematical modelling of the speed at which infectious individuals infect others, are critical to how public health agencies, the NHS and other organisations control the spread and plan for supporting communities and individuals.
3. The Merseyside Resilience Forum (MRF) is the statutory coordinating body within the region responding to increased demand for medical and social care, and coordinating other local public services to minimise the impacts of the pandemic. Modelling infection rates is key to informing COVID-19 planning and response in Merseyside.
4. The Lancaster-Liverpool COVID-19 Demand Model is introduced within this briefing, which estimates the potential impact of COVID-19 on health and care services within Merseyside. This model predicts, among other things, the anticipated timing and size of the epidemic peak and the number of people likely to fall sick each day.
5. Early lessons learned from application of the model encompass data and information access, openness and transparency, the streamlining of intelligence across different Local Resilience Forums and the benefits derived from multiple agencies joining forces in a unified command structure. A Civic Data Cooperative to provide shared intelligence to a command centre across NHS, local authority and academic regional partners is also advocated.

1. Introduction

The emergence of COVID-19 as a global threat in early 2020 triggered a variety of responses from local, national, and international agencies. These responses have been rehearsed in scenario planning for influenza, which bears some similarities in symptoms and how it is spread. However, SARS-CoV-2, the virus that causes the COVID-19 illness, is new – there is no pre-existing immunity in populations; it is more infectious than influenza; it can cause a fatal inflammation of the lungs; and there is no vaccine yet.

An important part of planning to control COVID-19 is for epidemiologists to understand how it spreads. For epidemiologists to be able to estimate infection rates (the speed at which infectious individuals infect others), they need data from large numbers of people infected with SARS-CoV-2, and information about what happens to them afterwards. This enables us to understand how the virus progresses through the body, from initial infection to when individuals become infectious, as well as the expected duration of symptoms and outcome. This information is critical to how public health agencies, the NHS and other partner organisations plan for supporting communities and individuals.

The purpose of this briefing paper is to set out how such information informs COVID-19 planning and response in Merseyside through the Merseyside Resilience Forum (MRF) – the statutory coordinating body responding to increased demand for medical and social care, and coordinating other local public services to minimise thempacts of COVID-19 on our residents.

2. Mathematical modelling of infectious disease transmission

Mathematical modelling is a central tool in understanding the spread of infections and predicting the course of an epidemic in a population. Such models are commonly used in policy-making. Modellers use information collected on numbers of people infected, percentage hospitalised, percentage discharged recovered, etc., to inform their predictions. The main mathematical, statistical, and epidemiological methods used are well established in public health practice. However, several different approaches are used to do this, and each has their own benefits and limitations. Similarly, in aviation, autopilot systems use a jury of models and do not just rely on one.

There are several groups of modellers who have been working on COVID-19 in the UK. Most are based in universities, and their modelling outputs are assessed by SPI-M (the Scientific Pandemic Influenza Group on Modelling). This expert committee provides guidance to the UK Government. Modelling is tailored to specific requests, such as the demand on NHS bed capacity and staffing. The results of modelling during an epidemic enable the Government to make decisions on when to introduce control measures, such as the closure of schools and public places, working from home and social distancing.

The most accurate models draw on specific local information. The MRF has a Health Intelligence Cell (HIC), with membership drawn from health, social, civic, academic and voluntary sectors and with a remit to provide actionable intelligence, data and recommendations around system demand and capacity in the COVID-19 pandemic. The HIC sits as one of 10 cells within the MRF reporting to the MRF strategic and tactical oversight groups. The MRF HIC is being supported by a team of modellers based at the Universities of Liverpool, Lancaster, and Manchester. The modelling assumptions are evidence-based and refined with clinical, public health and system-wide inputs.

3. The Lancaster-Liverpool COVID-19 Demand Model

Initial modelling has focused on estimating the potential impact of COVID-19 on health and care services within Merseyside (five Local Authority Districts (LADs): City of Liverpool, Sefton, Knowsley, St Helens and Wirral) to aid stakeholders in capacity planning. The model also supports planning in the wider Cheshire and Merseyside (C&M) NHS geographical planning area.

The Lancaster-Liverpool COVID-19 Demand Model has been developed, following iteration of an earlier developed Lancaster COVID-19 epidemic model, using national data on infection rates, hospital pathways/ usage (admission, ICU, discharge, mortality) and further modelling parameters obtained from published evidence and systems intelligence (Figure 1).

The model predicts pandemic progression at a C&M and local authority level, including:

- the anticipated timing and size of the epidemic peak
- the number of people likely to fall sick each day
- consequent intensive care unit (ICU) / non-ICU bed demand
- predicted daily mortality
- the number of patients anticipated to be discharged each day

Development, maintenance and use of the model

A summary of projections from the model is released weekly, alongside recommendations to the MRF. HIC activity is part of wider North West and national modelling activity led by Public Health England (PHE), which itself feeds into NHS England and Improvement and other organisations. The modellers in the North West meet at least weekly to share experiences over a family of models for different geographies and purposes.

There are currently some differences between the Lancaster-Liverpool COVID-19 Demand Model and models being used nationally. The local estimates produced by our model are substantially lower in terms of the overall trajectory and levels of predicted care need than estimates based on the 'reasonable worst case' scenario agreed nationally by the government's Scientific Advisory Group for Emergencies (SAGE). The first version of the Lancaster-Liverpool model assumed that recent control measures (school and business closures; restrictions on non-essential movement outside homes) would have a limited effect. Subsequent versions of the model directly estimate the impact of control measures implemented since 23 March 2020 from the epidemic case data. The model augments other information used in local NHS and social care capacity forecasting.

Inputs to and outputs from the model

The Lancaster-Liverpool COVID-19 Demand Model is a hybrid model with a transmission model feeding its output to a healthcare demand model. The transmission model is a dynamic infectious disease transmission model that takes into account the age group profile of local populations and social mixing patterns between people of different ages, as well as transport data and interactions between locations, in order to represent how the epidemic is likely to spread across the region. The model outputs are then used to explore the probable spread of SARS-CoV-2 and the demands on services caring for people with COVID-19.

The technical classification of the model is a deterministic SEIR (Susceptible, Exposed, Infectious, Recovered) meta-population model. The population is divided up into LAD geographies and 5-year age/sex groups, using the 2011 census to estimate the number of people in each age/sex group by district. The structure of contacts between LAD residents that may lead to SARS-CoV-2 transmission is based on previously measured social mixing information (the POLYMOD survey data) – this is a quantitative, evidence-based way of considering how contacts between people may transmit infectious diseases spread by breathing or close contact (see Mossong et al. 2008). To emulate the effect of school closures, the information from POLYMOD was modified to exclude contact between school-age children outside of the household after 23 March 2020. Transmission of the virus between LADs is assumed to follow commuting patterns, derived from 2011 census commuting data, which are down-scaled each day during the epidemic period, using transport data, relative to February, which showed a marked decline leading up to and following 23 March 2020.

Using output from the transmission model (on the number of new symptomatic infections per day, by age group and location), the model calculates the following down to local authority district level:

1. number in each age group that will seek care
2. number in each age group that will seek care and be admitted
3. number admitted in each age group that require a bed in an ICU
4. number admitted to non-ICU beds discharged per day

5. number admitted to ICU beds discharged per day
6. number admitted to non-ICU beds that die per day
7. number admitted to ICU beds that die per dayA summary of the model parameters is given in Figure 1.

Comparing Lancaster-Liverpool COVID-19 model with the output from applying the national Reasonable Worst Case Scenario model to the local population, the latter predicts 18% fewer infections, 35% fewer people needing hospitalisation or intensive care, and 36% lower peak demand on intensive care beds. The current model does not fully consider the impact on transmission of recent control measures. It should therefore be understood and interpreted as a worst case scenario projection. There is considerable uncertainty around the estimates, particularly for smaller geographic areas.

Figure 1: Lancaster-Liverpool COVID-19 Demand Model main parameters and assumptions

Parameter	**Assumption/Estimate**	**Source**
Latent period (time from being infected to being infectious)	4 days	Assumed
The hospitalisation rate (% of infections needing hospital admission)	8% (varying by age from <50 – 2%; >80 – 44%)	PHE Joint Modelling Cell
Intensive Care Unit (ICU) rate (% of hospitalisations needing an ICU bed)	25 % (varying by age – peak rate at age 60 reflecting current age distribution of COVID-19 patients in ICU)	25% admitted to ICU from Covid-19 NHS dashboard applying the age distribution from ICNARC
Onset to attendance at hospital emergency department (ED)	Gamma distribution (shape=2, rate=3.4), with median 4 days	Estimated from CO-CIN UK patient data
ED to Admission	Same Day	Assumed
Admission to ICU	Poisson distribution, mean 1 day	Assumed
Admission (general) to discharge	Uniform distribution, 4-8 days	Zhou 2020
ICU to discharge	Uniform distribution, 10-14 days	Guan 2020

4. Early lessons learned

1. **Data and information access**: Usual data and information sharing channels were too fragmented or slow for responding to the rapidly evolving situation. So, we linked frontline analysts with academic modellers in a secure online cipha.slack.com collaboration environment, which helped new teams to form quickly.

2. **Openness and transparency**: Open access to algorithms and documentation in public repositories helped different modelling teams refine their work with inputs from wider networks. Best governance of when to open a model for public consumption needs further reflection.

3. **Streamlining intelligence**: A core modelling team working across different Local Resilience Forums in North West England have organised weekly meetings and collaborate in technical and applied cipha.slack.com channels.

4. **Command centre**: Multiple agencies have started to join forces in a unified command structure, which is essential for acting coherently on the intelligence provided. The need for a Civic Data Cooperative to provide shared intelligence to a command centre across NHS, local authority and academic regional partners has become starkly apparent in the COVID-19 pandemic.

For more information on the Lancaster-Liverpool COVID-19 Model, including the associated code please see https://liverpoolhealthpartners.org.uk/spark/coronavirus-covid-19-and-research-across-lhp/data-and-modelling-of-covid/

5. References

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