ON LINE INTERNATIONAL SYMPOSIUM

Credibility of scientific expertise and decision-making

New challenges for health risk governance in a changing world

anses

COVID-19 SESSION

The magic of models, the celebrity of ‘Modellers’. Drivers of epidemiological modeling in the Age of Covid-19

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Avis du Conseil scientifique COVID-19
12 mars 2020

De manière plus précise, le Conseil scientifique a en particulier pris en compte les éléments suivants :

- Les résultats des modèles mathématiques qui, avec toutes les limites et incertitudes déjà évoquées, ne sauraient en aucun cas être la base unique d'une décision de Santé Publique. Ils doivent être pris comme un élément parmi d'autres pour informer le décideur. Le décideur doit prendre en compte les très nombreuses incertitudes et la situation évolutive. Notre rationnel scientifique est le suivant :
  - Impact : Si on laisse le virus se propager dans la population, étant donné sa forte transmissibilité, on s'attend à ce qu'au moins 50% de la population soit infectée après une ou plusieurs vagues épidémiques (Anderson et al, 2020). Pour un niveau de mortalité qui est actuellement estimé à 0.5-1%, cela correspond à des centaines de milliers de morts en France avec une surmortalité importante due à la saturation des services de réanimation (Anderson et al., 2020).

How will country-based mitigation measures influence the course of the COVID-19 epidemic?

*Roy M Anderson, Hans Heesterbeek, Don Klinkenberg, T Déirdre Hollingsworth
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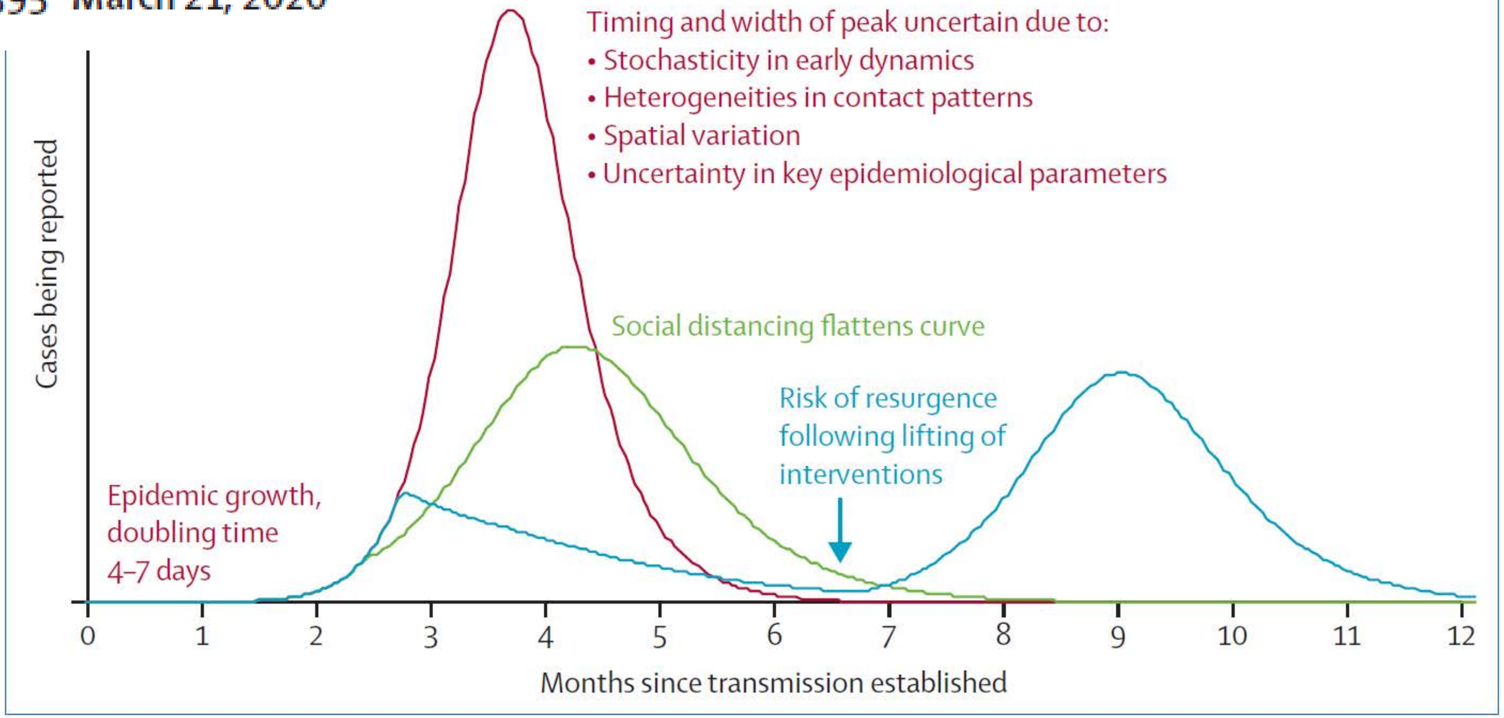

Figure: **Illustrative simulations of a transmission model of COVID-19**
A baseline simulation with case isolation only (red); a simulation with social distancing in place throughout the epidemic, flattening the curve (green), and a simulation with more effective social distancing in place for a limited period only, typically followed by a resurgent epidemic when social distancing is halted (blue). These are not quantitative predictions but robust qualitative illustrations for a range of model choices.

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The course of an epidemic is defined by a series of key factors, some of which are poorly understood at present for COVID-19. The basic reproduction number (R_0), which defines the mean number of secondary cases generated by one primary case when the population is largely susceptible to infection, determines the overall number of people who are likely to be infected, or more precisely the area under the epidemic curve. For an epidemic to take hold, the value of R_0 must be greater than unity in value. A simple calculation gives the fraction likely to be infected without mitigation. This fraction is roughly $1–1/R_0$. With R_0 values for COVID-19 in China around 2·5 in the early stages of the epidemic,[2] we calculate that approximately 60% of the population would become infected. This is a very worst-

Le R0 dans les différents départements de France, le 11 juillet 2020 (capture d'écran réalisée le 17 juillet 2020) Crédit : Capture d'écran RTL/Ministère de la Santé

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nombre total de cas reste élevé. Cette intuition a été illustrée à travers la réalisation d'un modèle COVID19 particulier (Neil Ferguson, communication personnelle). Ce modèle est adapté d'un modèle précédemment utilisé pour évaluer l'impact des stratégies de contrôle de premier niveau dans une pandémie de grippe (Ferguson et al, 2006 ; Luca et al, 2018 ; Ferguson et al, 2005). Ce modèle reste une référence pour la planification des pandémies. Cette réalisation de modèle a été présentée pour illustrer le raisonnement scientifique détaillé ci-dessus et aider les décideurs à comprendre les différents scénarios. Elle confirme les observations faites à l'étranger.

Neil Ferguson, l’épidémiologiste qui murmure à l’oreille de Downing Street

Au Royaume-Uni, c’est sur la base des modèles de ce chercheur que le premier ministre, Boris Johnson, a finalement décidé le confinement de la population.

Le Monde March 30th 2020

Vittoria Colizza : le virus de la recherche

Physicienne de formation, la chercheuse italienne dirige une unité Inserm spécialisée dans la modélisation des épidémies, notamment celle du nouveau coronavirus SARS-CoV-2.

Le Monde Feb. 17th 2020

What is a model ?

A mathematical representation of reality,
constructed and validated by observations,
that aims at understanding, analyzing and eventually act upon it,
dependent on theory and on data

A reductionist and simplified version of reality

Guided by specific scientific questions, hypothesis, styles of thought and data available

« All models are wrong but some are useful » George Box (1979)

Diversification of model nature and functions (Armatte and Dahan, 2004)

- With the increase in computing capacities, modelling approach have diversified
- New simulation-based approach have been developed to optimize the management of phenomena rather than explaining them
- Production of specific forms of anticipations, referred to as scenarios
- Complex relationship with data

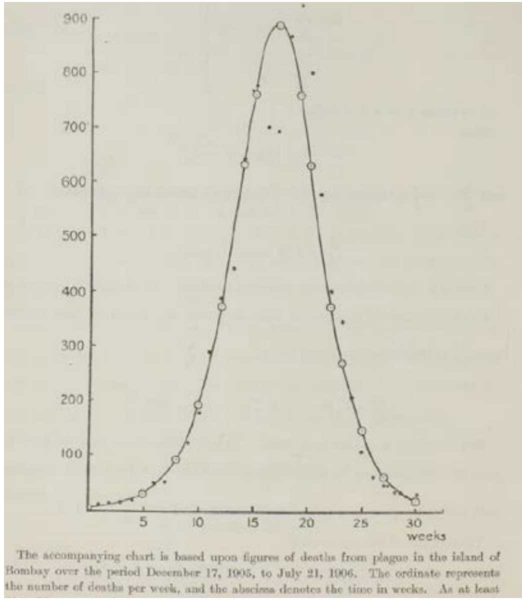
Models for epidemiology of infectious diseases

A Contribution to the Mathematical Theory of Epidemics.

By W. O. Kermack and A. G. McKendrick.

(Communicated by Sir Gilbert Walker, F.R.S.—Received May 13, 1927.)

(From the Laboratory of the Royal College of Physicians, Edinburgh.)



Poor data on a Plague epidemy on an island of Bombay

- Explain sporadic occurrence of large epidemics
- Get insight on the various factors which govern epidemics
- Asumptions : infection is random,
  all individuals equally susceptible,
  immune response is complete,
  pathogen is stable
- Three key parameters (infectivity, recovery and death rate) summarize the epidemy dynamics

A model with a remarkable legacy

- Dominant framework for most current models (R0)
- Complexified with new questions :
  - Proportion of the population to be vaccinated in order to control known diseases (measles, chickenpox…)
  - Allow for heterogeneous mixing – varying risk of infection depending on sexual practices (HIV), network of connexions (HIV, flue), geographic location… (Flue, SRAS…)
- Complexified with new data, scientific and disciplinary skills

Models for infection diseases in context

- Need for a sociological approach of model analysis : who produces them ? In which institutions ? With what kind of knowledge, know-how and technologies ?
- The particular position of infectious disease epidemiology after World War II
- Focus on two recent COVID19 models and modellers
  - Neil Ferguson and Marc Lipsitch

16 March 2020 Imperial College COVID-19 Response Team

Report 9: Impact of non-pharmaceutical interventions (NPIs) to reduce COVID-19 mortality and healthcare demand

Neil M Ferguson, Daniel Laydon, Gemma Nedjati-Gilani, Natsuko Imai, Kylie Ainslie, Marc Baguelin, Sangeeta Bhatia, Adhiratha Boonyasiri, Zulma Cucunubá, Gina Cuomo-Dannenburg, Amy Dighe, Ilaria Dorigatti, Han Fu, Katy Gaythorpe, Will Green, Arran Hamlet, Wes Hinsley, Lucy C Okell, Sabine van Elsland, Hayley Thompson, Robert Verity, Erik Volz, Haowei Wang, Yuanrong Wang, Patrick GT Walker, Caroline Walters, Peter Winskill, Charles Whittaker, Christl A Donnelly, Steven Riley, Azra C Ghani.

On behalf of the Imperial College COVID-19 Response Team

WHO Collaborating Centre for Infectious Disease Modelling
MRC Centre for Global Infectious Disease Analysis
Abdul Latif Jameel Institute for Disease and Emergency Analytics
Imperial College London

- Individual-based simulation model developed to support pandemic influenza planning
- Wuhan data for disease transmission parameters
- Census and mobility data embedded to model types of contacts
- Hypotheses on infectivity, immunity
- Hypotheses on disease characteristic

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- Critics on the many hypotheses regarding disease transmission, healthcare system parameters...
- Critics on the methods : complexity of the simulation process, lack of reproducibility, methods for statistical inferences
- Contrasted impact on political decisions : France and UK

Neil Ferguson, Imperial College London

- PhD in Theoritical Physics
- Post-doc with R. May and R. Anderson in Oxford.
  Trained and socialized in the epidemiology modelling tradition.
  Work on measles vaccination strategy, scenario of small pox attacks (optimizing control strategies)
- Leading modeller on foot and mouth disease (2001). Use real time data on spatial and temporal patterns of disease spread, to make prediction of future incidence and simulate control strategies
- Brings computer intensive simulation practices – to incorporate big data available (on disease pattern, behavior and effects of control strategies) and adapt modelling practices to increased model sophistication

REPORT

Projecting the transmission dynamics of SARS-CoV-2 through the postpandemic period

Stephen M. Kissler[1,*], Christine Tedijanto[2,*], Edward Goldstein[2], Yonatan H. Grad[1,†,‡], Marc Lipsitch[2,†,‡]
+ See all authors and affiliations

Science 22 May 2020:
Vol. 368, Issue 6493, pp. 860-868
DOI: 10.1126/science.abb5793

- Modelling the epidemics dynamic over a 5 year period, with attention on the duration of immunity, cross-immunity and season effects
- Time series data for previous coronavirus immune response
- Simpler model for contacts in the population, fine effects of intervention
- Shows the impact of the type of immune response, in the longer-term. Calls for serological data collection

Marc Lipsitch, Harvard School of Public Health

- PhD in zoology at Oxford on pathogen virulence evolution
- Post-doc on evolutionary biology of bacteria (B. Levine) and at the CDC
- Work on streptococcus pneumoniae (**immune responses, population biology and genomics, antibiotic resistance) and on pandemic preparedness and response (SRAS, H1N1)**
- Brings evolutionary biology perspectives, attention to environnemental parameters and data

Epidemiology

Big data and simple models to track COVID-19

Nature | Vol 589 | 7 January 2021 |

Kevin C. Ma & Marc Lipsitch

Understanding the dynamics of SARS-CoV-2 infections could help to limit viral spread. Analysing mobile-phone data to track human contacts at different city venues offers a way to model infection risks and explain infection disparities. **See p.82**

On page 82, Chang *et al.*[1] present an innovative method that combines simple infectious-disease models with human-mobility data obtained from mobile-phone records. This data-rich model has enabled them to generate and, to some extent, test hypotheses on where the virus is transmitted, how racial and socio-economic disparities in COVID-19 infections arise, and how effective different types of control measure might be.

Opening (rather than a conclusion)

- Rising importance of simulation-based modelling approaches aiming at optimizing the management of epidemics
- Efforts on collecting and managing big data
- Anticipations still require finer comprehension of phenomena

➔ Need for fine grained analyses of modelling practices, impactS of scientific trajectories, technologies and institutional positions, with an attention to local and national configurations