Modeling Infectious Diseases: Introducing a model and simulation tool to support pandemic preparedness planning

By Ralf Krumkamp, Mart Stein & Irwin Chavez
Models ...

• ... are a simplified presentation of the reality
• ... define relevant characteristics of a subject to make it suitable for analysis
Why model infectious diseases?

- *Gain insight into mechanisms* influencing disease spread.
- *Focus and clarify thinking:* model formulation forces to make clear statement of assumptions, hypotheses.
- *Derive new insights and hypotheses* from mathematical analysis or simulation.
- Explore *intervention options* to inform policy.
- *“What if”-experiments* since real experiments are often logistically or ethically impossible.

(Hesterbeek and Roberts, 1995)
Informing health policy

Isolation and contact tracing

Isolation:

• useful for infections not transmitted before symptom onset
• useful if large proportion of the cases can be isolated

Contact tracing:

• especially for infections transmitted to close contacts
• if infected individuals traced before they show symptoms

(Hollingsworth, 2009)
Vaccination
- reduces the number of susceptible individuals so that the epidemic cannot sustain

Antiviral prophylaxis
- if (i) enough doses available, (ii) programme is implemented rapidly, and (iii) cases occurred in a confined region
- large scale prophylaxis entails the problem of antiviral resistance

(Hollingsworth, 2009)
Modelling infectious diseases

Models are not crystal balls!

- Models are tailored to a certain research question
- Available data determines the possible complexity of a model and the quality of the output
- A balance between simplicity in application and accuracy in modelling
The SIR model

Individuals affected by an epidemic move through a number of disease states, based on the natural history of infection.

**SIR:**

- S (Susceptible)
- I (Infected)
- R (Removed)

![Graph showing the proportion of susceptible, infected, and recovered individuals over time.](image-url)
The AsiaFluCap Simulator

**Aim:** estimate health service resource needs for pandemic influenza control and prioritise resources to be improved

**Resources considered:**
- Antiviral drugs
- Vaccines
- Respirators
- Hospital beds
- Personal protective equipment
- Health care workers

**Effect on cases / deaths**
The simulator cannot:
• predict outbreak progression
• predict the actual amount of resources needed
• give age-sensitive results

The simulator can:
• prioritise resources which should be scaled-up
• link resource gaps to their relative number of avoidable deaths
The AFC Simulator

Development of a simulation model to guide health care resource planning during pandemic influenza
Pandemic planning (evidence based) is essential, but challenging and requires data. Therefore, tools needed...
Goal tool: The AFC Simulator

User-friendly tool to support policy makers, policy advisors, donors and other stakeholders involved in pandemic preparedness and health care resource allocation at national, regional or local levels.

-> Simple model for providing evidence based scenarios, focused on health care resources (= unique)
-> Guidelines, training and exercises (e.g. Table Top Exercise)
The AFC Simulator
“What if...?”

> Severe influenza outbreak in region...?
• Indication impact on public health
• Highlight possible resource gaps
• Prioritizing between resources, which resources gaps should be attended first?
• Resource mobilisation/re-allocation in regions
• ...
Methods I: structure of the AFC Simulator*

Influenza outbreak model**

Resource depletion model
(29 key health care resources!)

Occupied and depleting resources...

* ML. Stein et al. The AFC Simulator. (In preparation)
**R. Krumkamp et al. Epidemiol Infect. 2011 Jan
Methods II: requirements for the AFC Simulator

- Built in MS Excel®, MS Visual Basic® shell)
- Data on resource availability, population size

User-friendly! No extensive modelling expertise required.
AFC Simulator will be available on www.asiaflucap.org
Methods III: Included pandemic scenarios AFC Simulator

- Mild pandemic scenario (based on H1N1 parameters)
- Severe pandemic scenario (based on H5N1 parameters)

-> Adjustment to other scenarios, resources, diseases (eg. SARS) possible...
Indication on the moment of depletion of resources. Pandemic peak critical phase...

Results I: Output AFC Simulator

- Gloves
- Surgical masks
- Antiviral stockpile

Critically ill hospitalised
Total number of deaths
Total number of ventilated cases
Results II: Output AFC Simulator

Available, needs and gaps of occupied resources (at pandemic peak)

Highlighting possible gaps during peak...
Displaying output AFC Simulator
Geographical displaying of results, for a clear presentation.

Linkage with GIS provides new possibilities for using the data...
How to present the output data from the AFC simulator?

• Statistical tables

• Charts

• Maps
What is GIS?

- GEOGRAPHIC INFORMATION SYSTEM
- Management of large amounts of information
- Allows for quick visualization of data on a map
- Ability to describe spatial patterns
Map layers

- Point
- Line/Polyline
- Area/Polygon
ESRI shapefile

• Composed of at least 3 files
  – *.shp
  – *.shx
  – *.dbf
• *.dbf – from dBase software
  – Can be opened, edited, and saved in MS Excel 2003 and earlier
How does a GIS function?

- **Base maps**
  - digitized/digital maps with core geographic features
    (administrative boundaries, rivers, roads, elevation, villages, etc)

- **Attribute databases**
  - Public health databases (survey results, census, surveillance data, health information systems, programme monitoring indicators, etc)

- **Data are linked to a digital map by a geo-reference**
  - (such as the name or ID of digitised boundary map or to the geographic coordinates of a point, such as a village)

- **GIS/mapping software**
  - to create the geo-reference and manage the database alongside basemaps
  - generate, view, and customize thematic maps
Free GIS software

- WHO HealthMapper
  http://www.who.int/health_mapping/tools/healthmapper/en/

- Quantum GIS/GRASS
  http://www.qgis.org/wiki/Download

- MapWindow GIS

- uDIG
  http://udig.refractions.net/download/
Licensed GIS software

- MapInfo Professional
- ArcView/ArcGIS
- Maptitude
- Autodesk
- ERDAS Imagine
- others
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