



# Approaches to modelling serogroup A meningococcal disease in Africa

**Tom Irving**<sup>a,b,c</sup>, Caroline Colijn<sup>d</sup>, Konstantin Blyuss<sup>e</sup>, Caroline Trotter<sup>b</sup>

tom.irving@bristol.ac.uk

# **Background and Aims**

• Serogroup A meningococcal meningitis is a major public health problem in the African meningitis belt, where large epidemics occur frequently but unpredictably. A new vaccine is being introduced in the region against the disease. However, the dynamics

## **2. Age-structured Deterministic Models**

**Motivation** Both meningococcal carriage and meningitis affect different age groups at different rates and different vaccination strategies may target different age groups. An age-structured model is therefore required.

of the infection are still poorly understood.

• Mathematical models have been widely used to improve understanding of infectious diseases, and are often used by policy makers, for example, to inform strategies against emerging infections and to help to decide on optimal vaccination policies. • We outline a variety of mathematical modelling approaches being used to investigate

the dynamics of meningococcal meningitis in the African meningitis belt.

- Key issues to be addressed include:
  - the relative importance of population immunity
  - o the role of seasonal changes in transmission vs changes in the case:carrier ratio
  - the occurrence of small localised epidemics vs epidemic waves covering a much larger region
  - the predicted impact of a range of vaccination strategies

# **1. Simple Deterministic Models**

**Motivation** Simple models can be very useful for understanding complex systems. We developed a simple model of meningococcal carriage and disease, which aimed to capture some of the key features of the disease epidemiology on a national scale, i.e.

**Methods** Using methods adapted from Hethcote [2], we have extended our simple model and developed an age-structured deterministic model using demographic data for countries in the meningitis belt.

Fig. 3. The distribution of age groups in Burkina Faso (blue) and the one used for our model (red).



**Future work** We will estimate age-specific parameters and compare the dynamics of the age-structured and simple models. The model structure will then be extended to include vaccination, and the model will be used to predict the potential impact of a range of immunisation strategies.

seasonal disease with periodic but irregular epidemics of different sizes. In particular, we used the model to examine the importance of population immunity and to explore how seasonality in acquisition rates and the case/carrier ratio affected model dynamics. **Methods** We developed a range of deterministic compartmental models, such as figure 1, which incorporated different assumptions regarding immunity (no immunity, immunity) following disease, immunity following carriage and disease) and seasonal forcing (acquisition of carriage, or progression from carriage to invasive disease).



Fig. 1. R: Flow diagram showing movement of individuals between classes in one of the deterministic models. L: Model simulation of weekly incidence per 100000 people showing epidemics of different sizes and frequencies

#### **Findings** These models suggested that

Repeated epidemics occurring at irregular intervals could be a result of waning

# **3. Stochastic Multi-population Models**

**Motivation** Although the deterministic models describe well the unpredictable recurrent epidemics on a national level, they cannot account for the observed spatial diversity in disease incidence. As described by Mueller and Gessner [3], in some years there are small localised epidemics and in others "epidemic waves" that can affect entire countries or regions. We wanted to investigate whether or not additional factors such as viral co-epidemics are necessary to explain epidemic waves.

**Methods** We have developed a multi-population model, consisting of discrete communities, as shown in Figure 3. Within each community, individuals can move stochastically between susceptible, carrier, invasive disease and recovered (immune) classes. The communities are interlinked so that infection can spread; individuals come into contact with those from other communities in inverse proportion to the distance between them.

Fig. 3. Schematic diagram of multi-population model. Within each community the model structure is similar Communities are positioned on a lattice. Inhabitants move between different states in each community and can pass infection to those in their own and other communities.



immunity and an increase in the risk of acquisition of carriage during the dry season.

- Seasonal variation in case:carrier ratio and differences in strength of seasonal effects between years were not required to cause such repeated epidemics
- Without a temporary period of immunity following carriage, such behaviour was not observed.

A complete description of methods and results is given in Irving et al. [1].

**Limitations** We did not consider heterogeneities in age or space (see opposite). Many of the model parameters were uncertain so we considered a wide range of values. Results from large multi-centre carriage studies (<u>www.menafricar.org</u>) will enable model parameters to be better estimated.

## References

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- 2. H.W. Hethcote. The mathematics of infectious diseases. SIAM review, 2000.
- 3. Mueller, JE, Gessner BD. A hypothetical explanatory model for meningococcal meningitis in the African meningitis belt. Int. J. Inf. Dis. 2009.



**Future work** We will improve our estimates of model parameters and simulate different scenarios using this model structure.

## **Affiliations and Acknowledgements**

<sup>a</sup> Bristol Centre For Complexity Sciences, University of Bristol <sup>b</sup> School of Social and Community Medicine, University of Bristol <sup>c</sup> Department of Engineering Mathematics, University of Bristol <sup>d</sup> Department of Mathematics, Imperial College London <sup>e</sup> Department of Mathematics, University of Sussex. TI is funded by EPSRC. CT is funded by the MenAfriCar consortium.

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