In order to explore the use of disease transmission modelling in cost-effectiveness analysis, a generalised deterministic compartmental transmission model was developed, Figure 1.

The model was integrated using Euler’s method, a time step of one day and a time horizon of 10 years. Discounting was applied to both costs and QALYs at an annual rate of 3.5%. Individuals were withdrawn from the model upon recovery or death, according to the incremental cost-effectiveness ratio (ICER) graphed by including treatment from week 10 following the introduction of a single infectious individual into a susceptible population of 10,000. Outcome was expressed as an incremental cost effectiveness ratio (ICER).

Sensitivity

The periodic nature of the peaks is better illustrated by a phase plot, charting the numbers of infectious individuals against the number of susceptibles, Figure 4. This shows increases in duration of immunity and treatment effect result in a disproportionate reduction in the population (ICER relative to the base case; ICER, Table 3. Increasing the base case treatment effect from 3 to 20 days results in the eradication of the pathogen from the population, reducing the population (ICER to near zero).

Discussion

In order to explore the impact of seasonal variation in the force of infection, the base case parameters were applied, varying the force of infection using a sine wave with a peak at one year and a range between zero and one. In order to explore the potential for an intervention to influence the pattern of disease dynamics, the duration of immunity was increased to 20 years and treatment effect to a 13 day reduction in the infectious period.

Table 3. Sensitivity Analysis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Base Case</th>
<th>No Treatment</th>
<th>Treatment</th>
<th>ICER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of baseline treatment</td>
<td>£3,771</td>
<td>£3,771</td>
<td>£3,771</td>
<td>£3,771</td>
</tr>
<tr>
<td>Cost of treatment</td>
<td>£14,641,146</td>
<td>£14,641,146</td>
<td>£14,641,146</td>
<td>£14,641,146</td>
</tr>
<tr>
<td>Utility of treated symptomatics</td>
<td>0.8</td>
<td>0.8</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Utility of untreated symptomatics</td>
<td>0.8</td>
<td>0.8</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Duration of immunity (years)</td>
<td>2</td>
<td>3</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

Over 10 years in a population of 10,000 individuals, treatment resulted in a saving of approximately £30,000 per QALY, Table 2.

Conclusions

1. For interventions that impact on transmission, taking account of the transmission dynamics of an infectious disease can significantly reduce the ICER and increase the probability of the treatment being deemed cost-effective.

2. Non-linear transmission models are sensitive to changes in certain parameter values, necessitating accurate estimation and careful selection of parameters.

3. Transmission models can take account of a rich diet of dynamic behaviours, including seasonal variation in prevalence and intervention induced changes in the epidemiology of disease.

References

1. The National Institute for Health and Clinical Excellence (NICE) recommends that “economic analyses relating to public health guidance should adopt the public health vector: NICE and personal social services perspective.” NICE draws on the second ‘Winnifred report’ into the cost-effectiveness of improving the health of the whole population which defines public health as “the science and art of preventing disease, prolonging life and promoting health through the organised efforts and informed choices of society, organisations, public and private, communities and individuals.” The study specifies a number of reasons why taking a wider population perspective is particularly informative when dealing with infectious diseases and the importance of dynamic transmission models in this approach. The limitations of this approach are also discussed.

Methods

Introducing a baseline model for the duration of immunity was increased to 20 years and treatment effect to a 13 day reduction in the infectious period.

Results

Disease prevalence. Table 3.

Sensitivities and associated costs.

The sensitivity of the estimated ICER to changes in each of the parameters is shown in the tornado diagram, Figure 3. The sensitivity assessment shows how the base case ICER with each horizontal slice of the tornado will vary. The range of ICERs obtained by varying the parameter named on the right of the diagram. The maximum and minimum ICER is noted next to each end of the bar, under which is the corresponding parameter value in curly brackets.

Sensitive to the estimated ICER to change in each of the parameters.