Introduction to Tuberculosis Modelling
48th World Union World Conference on Lung Health, Liverpool
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Practical 2: Modelling the impact and cost effectiveness of TB interventions

Solutions

Exploring the impact of improved diagnostics on the TB incidence and number of cases prevented

Q1. In the short term (1 year) we would expect the intervention to have very little impact on the disease incidence. In the longer term (10 years) we would expect to see a larger, but still relatively small, impact.

The short term impact on incidence is small because the intervention does not directly prevent cases, but does improve the diagnosis of existing cases. By improving the diagnostic pathway, the intervention reduces the duration of infectiousness in smear-negative cases so that each smear-negative case produces fewer new infections which can progress to TB disease. Therefore, over the longer term, the impact is increased due to the indirect effect of the intervention on transmission.

The long term impact is still relatively small because smear-negative cases only account for a small proportion of all TB cases (~30%) and are less infectious than smear-positive cases.

Step 1, page 4. The table shows the tuberculosis incidence, mortality and risk of infection predicted by the model with the intervention at the end of 2014 and the end of 2023. Within one year of the introduction of the intervention, the incidence has changed negligibly. Over 10 years, the intervention leads to a reduction in the incidence from 197 per 100,000 to 184 per 100,000, a reduction of approximately 7%.

	Without the intervention	**With the intervention**	
		End of 2014 (1 year)	**End of 2023 (10 years)**
TB incidence per 100,000 per year	197	197	184
TB mortality rate per 100,000 per year	51	47	42
Annual risk of infection (%/year)	2.4	2.4	2.2

Steps 2 and 3, page 4. The table below shows that the improved diagnostic makes very little difference to the number of cases in the first year after its introduction (2014) preventing just one case of tuberculosis.

	Without the improved diagnostic	**With the improved diagnostic**
Total number of TB cases in 2014	193	192

Q2. Assuming that the intervention prevents 1 case per year, you might expect the intervention to prevent at least 10 cases over 10 years.

Step 4, page 5. The model predicts that over a 10 year period, 1969 cases would have occurred in the population if the current diagnostic algorithm was used. With the new diagnostic test 1906 cases would occur. Therefore the new diagnostic test would prevent 63 (=1969-1906) cases over 10 years. This number is **more than** 10-fold greater than the number of cases prevented in 2014 (1 case) multiplied by the duration of the time period considered (10 years).

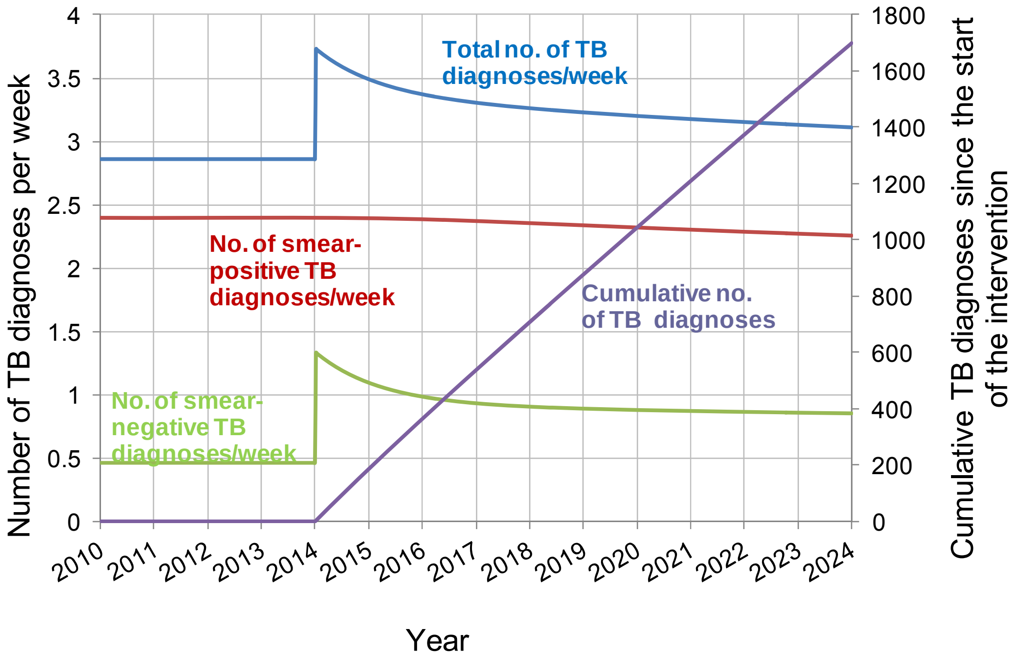
Q3. The number of cases prevented over a ten year period (63) is much higher than the number of cases prevented over one year multiplied by the duration of the time period considered (10 years), i.e. 10. The difference between these two numbers results from the effect of the intervention on transmission. As cases are prevented, the number of new infections occurring each year (i.e. the risk of infection) also declines, which means that the number of individuals who are at risk of progression to disease also decreases.

Q4. (optional) When the effective contact rate is very high (20 per year) the intervention prevents 98 cases over 10 years. The total number of cases prevented is higher than when the effective contact rate is 15 per year due to the increased background incidence. However the percentage reduction in the number of cases is the same (≈3%). This is because, as we saw in the supplementary questions of practical 1, the amount of disease due to recent transmission remains relatively constant when the risk of infection changes.

Calculating the cost and cost effectiveness of introducing the new diagnostic

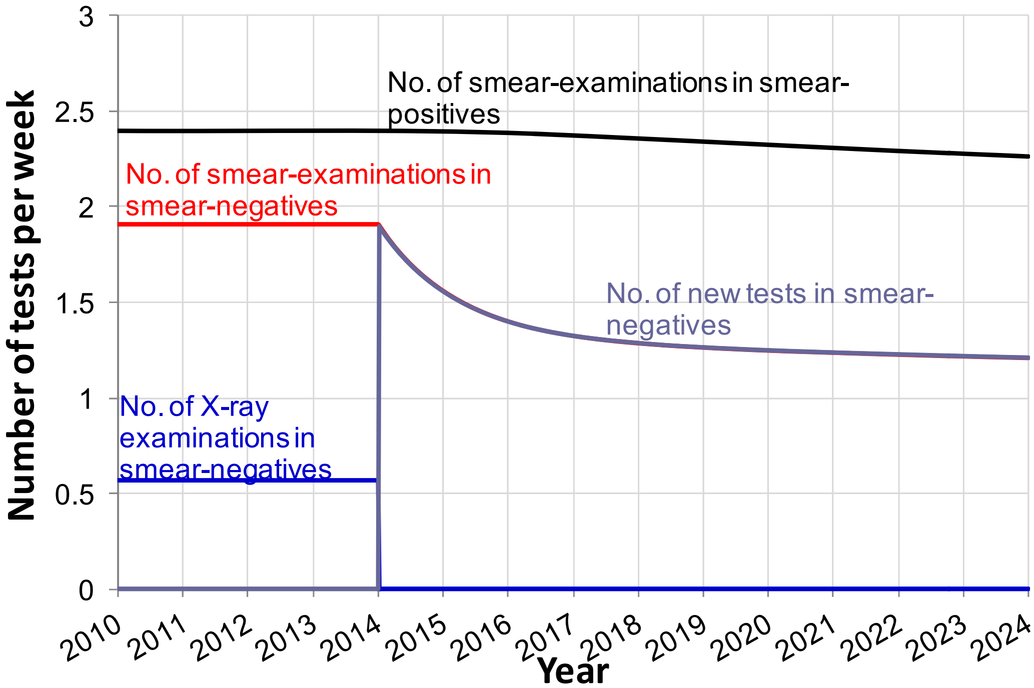
Q5. The number of diagnoses in smear-negatives will initially increase when the new test is introduced. This results from an increased number of cases being detected because of the increased sensitivity of the test, compared to that of X-ray. However as the tuberculosis incidence falls as a result of the intervention, the number of diagnoses in smear-negative cases will also fall.

As the diagnostic algorithm for smear-positive cases is unchanged you might expect the number of diagnoses of smear-positive cases to remain unchanged. However, the improved diagnosis of smear-negative cases leads to a small reduction in the number of infections resulting from each case, which in turn translates into a reduction in the incidence of smear-positive cases in the population.



Graph 3: The number of TB diagnoses per week following the introduction of the new diagnostic in 2014.

Step 1, page 5. The following figure shows what you would have seen in Graph 4.



Graph 4: Predictions of the weekly numbers of smear-positive and smear-negative TB cases whose sputum is examined using smear microscopy, the weekly number of tests carried out using the new diagnostic in smear-negative cases and the number of smear-negative cases who are examined using a chest X-ray.

When the new diagnostic is introduced, the number of examinations carried out using X-ray drops to zero, since all smear-negative cases are no longer examined using X-ray. The new diagnostic is now offered to all sputum smear-negative cases (compared to 30% of cases being offered X-ray before the intervention) so, when the new diagnostic is introduced, the number of new diagnostic tests used equals the number of sputum-smear examinations in smear-negative cases. (Note that if you click on the button for Num_new_test_for_smneg, at the bottom of the graph you will see that the line for the number of smear examinations carried out among smear-negative cases matches the line for the number of new diagnostic tests used for smear-negative cases). Over time, the numbers of all tests used in the new algorithm declines as the incidence of tuberculosis falls.

Q6. The cost associated with introducing the intervention is much greater than the cost of continuing with the current diagnostic algorithm ($249,256 compared to $86,423). The increased cost is a consequence of the increased cost of the new diagnostic test compared to X-ray ($20 vs $10) and the increased proportion of smear-negative cases offered the new test compared to the proportion offered X-ray (100% vs 30%).

Q7 a). The average cost effectiveness ratio (ACER) is given by the following formula:

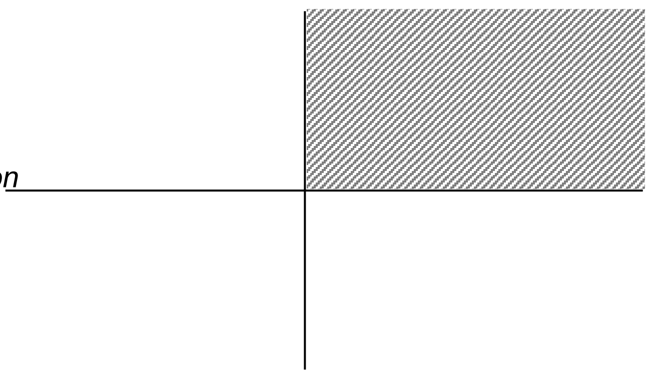
Total cost of intervention/Total impact of intervention

Using the number of cases diagnosed as our measure of impact the ACER is equivalent to the average cost per case diagnosed which is displayed in graph 6. If we continue with the current diagnostic algorithm the ACER = 58 dollars per case diagnosed; if the new diagnostic test was introduced the ACER = 147 dollars per case diagnosed.

b) This places the new intervention in the upper right corner of the cost-effectiveness plane. The new diagnostic test is more expensive than the existing algorithm but is more effective in diagnosing TB cases.

New intervention more costly

New intervention less effective



New intervention more effective

New intervention less costly

c) To assess which intervention was most cost-effective you would need information on the health impacts resulting from diagnosing more cases as a result of introducing the new diagnostic test. You would also require information on the willingness to pay threshold of the country.

Q8. (optional) If the population was larger that is at present, the cost per diagnosis would be correspondingly lower because the fixed costs associated with the introduction of the new diagnostic would be spread over a greater number of individuals.

Q9. (optional) Discounting reduces the value of intervention impacts which occur in the future so that a case averted in 10 years time is assigned a lower value then a case averted one year from now. If discounting of impacts was included in the model the impact of the intervention would be reduced and the ACER of the new diagnostic test would be higher. Discounting would also mean the ACER would be more constant over time as the increased impact over the long term which you saw in question 3 would be reduced in value.