Memo

12 May 2020

From: **Robin Swann**
Minister of Health

To: **Executive colleagues**

The Reproduction Number - R

1. The purpose of this paper is to clarify and explain the terminology used to describe and determine the Reproduction Number (R) as used in the context of the COVID-19 epidemic.

Terminology:

2. In relation to an infectious agent, the Basic Reproduction Number (R_0) of an infection is the expected number of cases directly generated by one case in a population where all individuals are susceptible to the infection (as was the case at the beginning of the current epidemic).

3. The Effective Reproduction Number (R or sometimes R_e) is the expected number of cases directly generated by one case in a population where a proportion of the population is immune (as is the case at present for COVID-19).

4. R does not have a fixed value but varies with time, and is likely to be different every day. R_t is used to denote the value of R at a fixed point in time.

5. From a purely technical point of view R_t is now the correct terminology to use, but in practice people have become used to R_0 or increasingly just to R on its own. R on its own is likely to be the preferred terminology when communicating with the public.

Interpretation of R:

6. When R is above 1, the transmission of an epidemic increases in an exponential fashion, resulting in more cases, hospital admissions and deaths. The greater the value of R above 1, the more rapid the increase.

7. When R is below 1, there is a fall in the number of cases, hospital admissions and deaths. The further R is below 1, the more rapid the fall will be. There may be a significant lag (in the case of COVID-19, 2-3 weeks) before a fall in activity of the infection is apparent.

8. R is unlikely to fall to zero until all of the population is immune, either as a result of recovery from infection or successful vaccination.

Determining the value of R:

9. There are multiple approaches which have been used to estimate R; there is no consensus around a single best approach.

10. At the start of an epidemic, R_0 can be calculated using individual-level contact tracing data. Once an individual is diagnosed, his/her contacts are traced and tested. R_0 is then computed by averaging over the number of secondary cases of many diagnosed individuals. This approach is based upon the simple definition of R_0. During the course of an epidemic, it would be possible to determine R by the same approach; however, in practice this is difficult to achieve and it is therefore not often used.

11. The standard approach to determining R during an epidemic is to use mathematical modelling. The most common approach uses an SIR model (susceptible-infectious-recovered) or a variation of it. Dozens of such models have been published and are in use throughout the world; there is no single standard model which everyone uses. Other approaches are sometimes used.

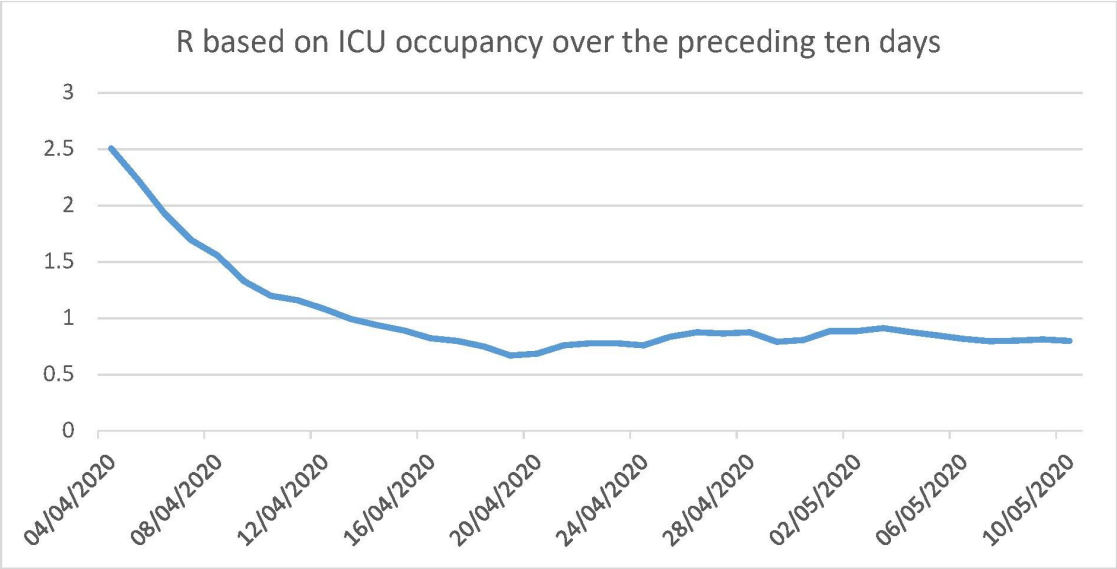
12. In addition to the impact of the mathematical model used, the calculated value of R is also influenced by the choice of input variable. R calculated for cases will not be the same as R calculated for hospital admissions, or ICU occupancy, or deaths.

Determining R for NI:

13. The number of COVID-19 cases detected depends heavily on testing strategy which continues to evolve, so it is not a useful number for modelling purposes. The most reliable number for modelling purposes during the course of the epidemic has been ICU occupancy, which has therefore been the main input variable which we have used to determine R. More recently we have also been determining R based on hospital admissions.

14. The main mathematical model which we have used is an SIR model developed within NI and calibrated using observed data in relation to the clinical pathway for COVID-19 patients in NI. However, we also have access to values of R calculated by a number of separate UK based modelling groups using different models and input data provided from NI. We therefore estimate R based on the outputs of a number of different models, rather than relying on a single model.

15. We determine R each day using our in-house SIR model and critical care occupancy data over the last ten days. R has generally been between 0.8 and 0.9 over the last two weeks. Today's value was 0.79 (95% confidence interval 0.65 – 0.94). The R value over the last few weeks calculated on this basis is shown in the figure below. A similar value is obtained when using hospital admissions data as the input source.



16. R has been recently determined for NI by UK groups using a range of different models with values given below:

University of Warwick 0.91 (0.85 – 0.95)
University of Manchester 0.68 (no confidence interval given).
University of Exeter 0.74 (0.57 – 0.93)

17. Each of these has compared R values across regions of England and the devolved nations on the same basis, which allows comparison between NI and the rest of the UK:

Warwick and Manchester models

			R
Location	**Warwick**	**Manchester**	
East of England	0.8 (0.75 - 0.83)	0.80	
London	0.71 (0.65 - 0.76)	0.69	
Midlands	0.75 (0.71 - 0.8)	0.70	
North East and Yorkshire	0.8 (0.76 - 0.85)	0.82	
North West	0.81 (0.78 - 0.84)	0.74	
South East	0.76 (0.69 - 0.82)	0.72	
South West	0.72 (0.63 - 0.79)	0.73	
England	0.77 (0.73 - 0.81)	0.74	
Wales	0.88 (0.84 - 0.91)	0.94	
Scotland	0.85 (0.8 - 0.89)	0.86	
Northern Ireland	0.91 (0.85 - 0.95)	0.68	

Exeter model:

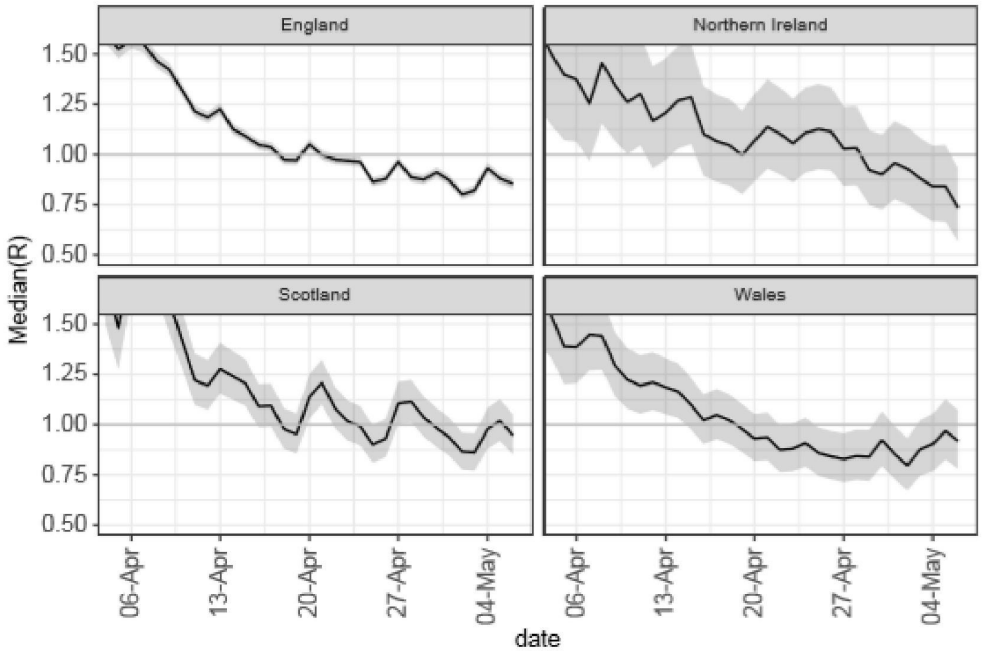


Figure 2: The timeseries of R(t) observations for the nations of the UK based on deaths

18. We have determined the R value for ROI using our model and ROI data on a number of occasions and have found the values to be broadly similar.

International comparisons:

19. The above data indicate how R varies when determined in different ways for NI and the UK. Similar or greater variation exists when comparing R for NI with other countries, as there may be differences in demographics or the provision of healthcare which influence R. Nonetheless, the same basic principles hold true – the epidemic declines when R is less than 1 and increases when R is greater than 1.