THE INITIAL AND DAILY COVID-19 EFFECTIVE REPRODUCTIVE NUMBER (R) IN SOUTH AFRICA

27 MAY 2020

NATIONAL INSTITUTE FOR COMMUNICABLE DISEASES
Division of the National Health Laboratory Service

OVERVIEW

Disease surveillance is a core function of the National Institute for Communicable Diseases (NICD), a Division of the National Health Laboratory Service (NHLS). This report includes an analysis of data on laboratory-confirmed cases of COVID-19 and laboratory testing to estimate the effective reproductive number (R) of SARS-CoV-2 over time in South Africa nationally and in selected provinces where sufficient data are available. The basic reproductive number (R0) is the average number of secondary infections produced by a typical case of an infection in a population where everyone is susceptible which occurs typically in the first few weeks after introduction of a novel infectious agent into the population. The R is the average number of secondary cases per infectious case in a population composed of both susceptible and non-susceptible hosts (once the infectious agent is circulating). If R>1, the number of new cases per time unit will increase, such as at the start of an epidemic. Where R=1, the number of new cases is stable over time, and where R<1, there will be a decline in the number of new cases per time unit.

This report is based on data collected up to 19 May 2020 (week 21 of 2020) and right censored for 14 days to account for delays in testing of collected samples and the time lag between symptoms onset and testing of infected individuals (R estimated up to 5 May). Note: COVID-19 is the name of the disease and SARS-CoV-2 is the name of the virus.

Highlights

- The initial R (estimation period: 19 days from introduction) in South Africa was estimated between 1.7 and 2.5 resulting mainly from transmission of infection from international travellers into South Africa.
- The flight restrictions and school closures announced in mid-March 2020 followed by the national level 5 lockdown appears to have substantially reduced the national R, likely contributing to substantially slowing the progression of the epidemic. R remains above 1, indicating that transmission is ongoing.
- In the Western Cape Province, the estimated initial R (estimation period: 17 days from introduction) was between 1.1 and 2.6 and the R in mid-late April 2020 was around 1.5-1.7 reflecting ongoing raising of the epidemic, but at a reduced rate from the time of introduction.
- In other provinces where estimation was possible (Gauteng, KwaZulu Natal and Eastern Cape provinces), the R in mid-late April 2020 was between 1 and 1.5 reflecting ongoing steady progression or raising of the epidemic but at a reduced rate compared to the Western Cape province and the time of introduction.
- Further easing of lockdown restrictions may be associated with increases in R in different provinces as contacts between people increase. Public adherence to physical distancing measures can have an important impact in reducing virus transmission.
- This analysis has important limitations. Changes in reporting cases and case definitions for testing may change over time, potentially affecting R estimation. While we attempted to adjust for changes in testing practice, residual bias may remain. Therefore, it is important to interpret these findings together with data on testing and other sources of data on transmission. In addition, caution should be exercised in interpreting comparisons between different timepoints and provinces as these could be affected by differential testing practices.

METHODS

Daily R estimation

We used data from the first confirmed case in early March until 19 May 2020 right-censored for 14 days to account for testing delays and estimation based on symptom onset date (last date of estimation: 5 May 2020). Data on date of symptom onset was 37% complete. Missing dates of symptom onset were imputed using chained equations multiple (100) imputations [i ,ii]. A negative-binomial model was fitted to confirmed COVID-19 cases for which the date of symptom onset was available and used to impute the date of symptoms onset for cases with missing information. The model predictors for imputation were: health sector (private vs. public), age, location (imported vs. locally acquired infections), day of the week (of sample collection), month (of sample collection) and province. We performed an adjustment for sample taking practices (e.g. shortage of reagents a few weeks after introduction) and rate of testing accounting for the daily variation of the ratio of positive and tested samples on consecutive days [1]. For the R estimation, imported cases were allowed only to transmit (but were not infectees). The daily R was estimated using the method of Wallinga and Teunis [iii] for each imputed dataset (100 time series generated through the multiple imputation process). For the serial interval we used a gamma distribution with mean of 5.3 and standard deviation 1.8. We report the median and 2.5th-97.5th percentiles of the estimated daily R values obtained from 100 imputed datasets [1,2].

Initial R estimation

The initial R was estimated during the initial exponential growth phase of the epidemic (15-19 days depending on provinces). Imported cases were allowed only to transmit (but were not infectees). The initial R was estimated from one epidemic curve obtained using median lag time from symptoms onset to date of sample collection from the 100 imputed time-series obtained as described above. This was done because the information on symptoms onset among the initial confirmed cases (used for the initial R estimation) were 89% complete. The initial R was estimated using the maximum likelihood method developed by White and Pagano [iv]. For the serial interval we used a gamma distribution with mean of 5.3 and standard deviation 1.8.

LIMITATIONS

The main limitation of this analysis is that changes in rate of reporting and testing and case definitions for testing may change over time potentially affecting R estimation. While we attempted to adjust for changes in testing practice, residual bias may remain. Therefore, it is important to interpret these findings together with data on testing and other sources of data on transmission. In addition, caution should be exercised in interpreting comparisons between different timepoints and provinces as these could be affected by differential testing practices.

RESULTS

The daily number of samples collected and tested for SARS-CoV-2 has steadily increased since testing began in early March 2020. However testing numbers decreased in week 19 (4-10 May). Reduced testing volumes were observed over weekends and public holidays. These data are available in the NICD COVID-19 Testing Summary.

Plotting the epidemic curve using the imputed date of symptom onset rather than specimen collection date resulted in smoothing of the curve (Figure 1).

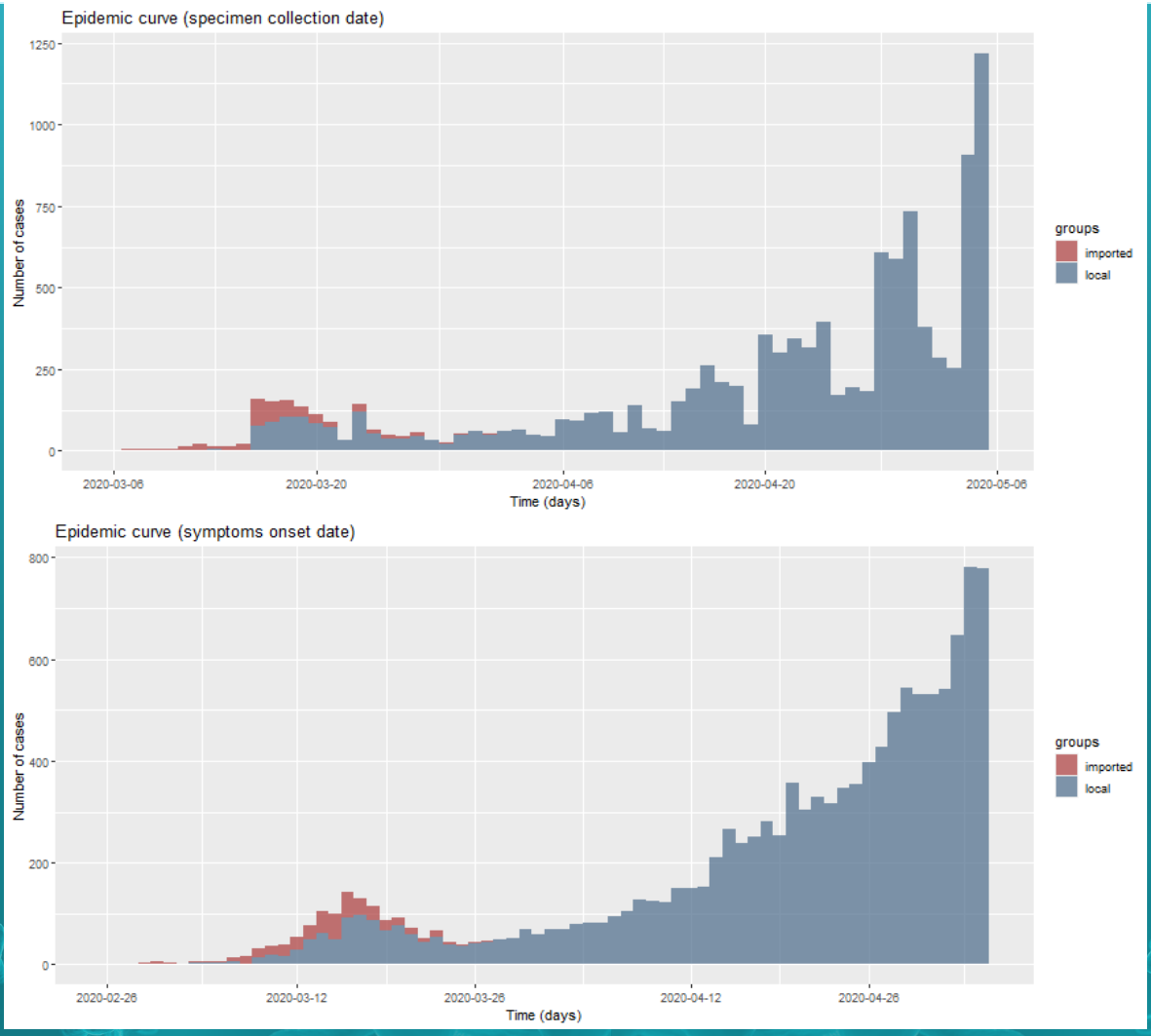


Figure 1. Daily number of SARS-CoV-2 positive samples by date of specimen collection and date of symptom onset (missing data imputed), South Africa (last date included: 5 May 2020)

Nationally, the initial R (estimation period: 19 days from introduction) was 2.07 (95%CI: 1.69-2.50) with transmission mainly from imported cases. The daily R dropped substantially during the period of flight restriction and school closures and has remained at around 1.5 during the stage 5 lockdown (Figure 2).

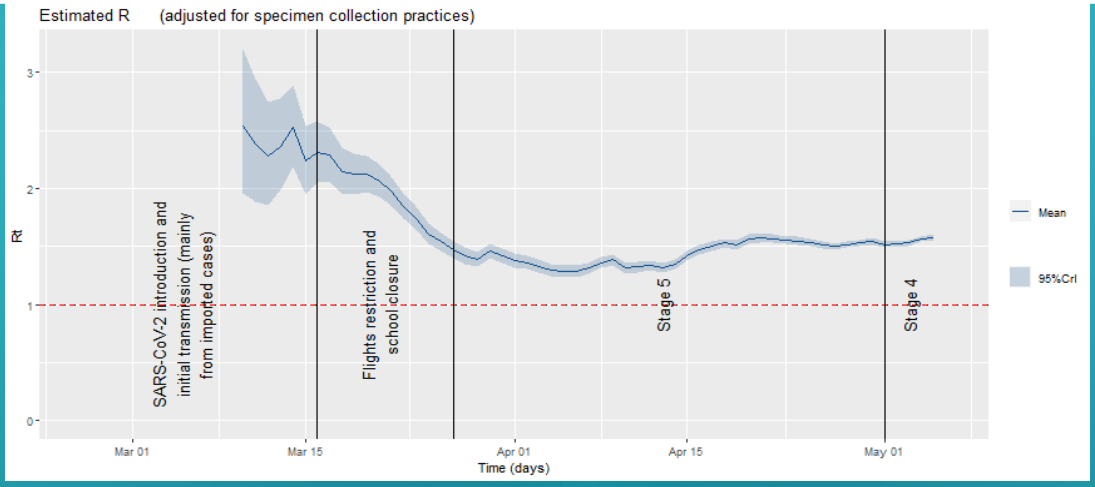
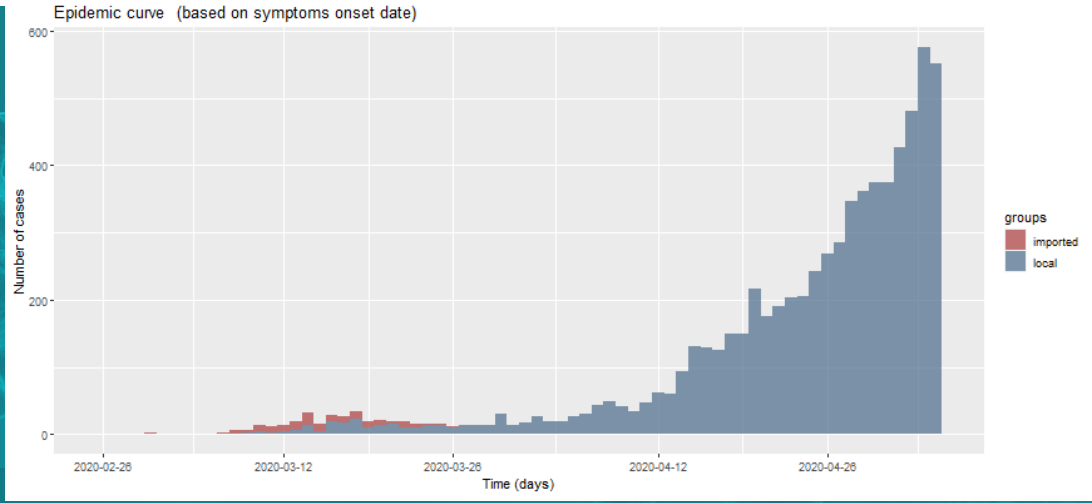


Figure 2. Estimated daily R adjusted for specimen collection practices, South Africa (last date included in the estimation: 5 May 2020)

In the Western Cape Province, the initial R (estimation period: 17 days from introduction) was 1.76 (95%CI: 1.11-2.62) with transmission mainly from imported cases. The daily R dropped substantially during the period of flight restriction and school closures and has remained at around 1.5 during the stage 5 lockdown (Figure 3).



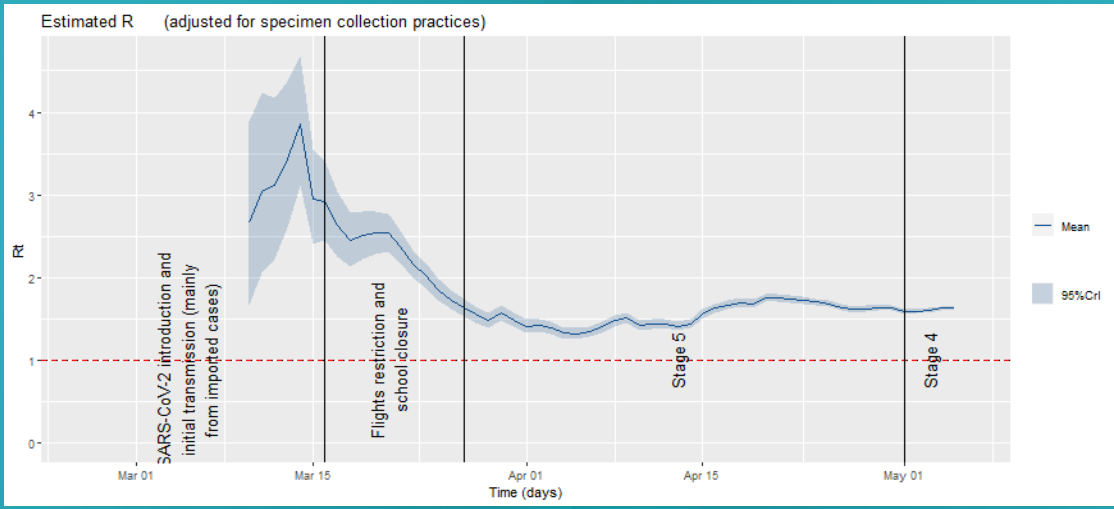
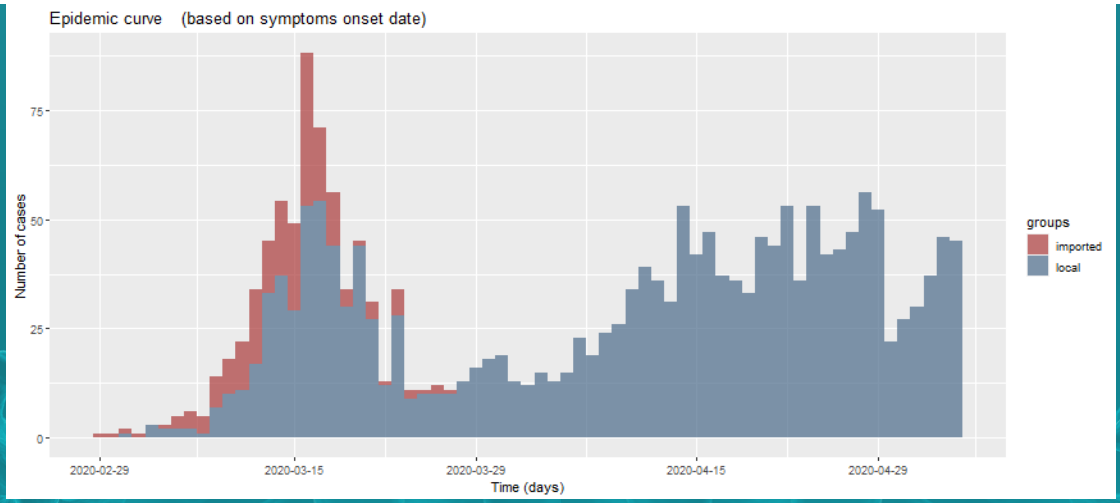


Figure 3. Western Cape (last date included in the estimation: 5 May 2020). Upper panel - Daily number of SARS-CoV-2 positive samples by date of symptom onset (missing data imputed). Lower panel - Estimated daily R adjusted for specimen collection practices

In Gauteng, the initial R (estimation period: 15 days from introduction) was 2.19 (95%CI: 1.95-2.39) with transmission mainly from imported cases. The daily R dropped during the period of flight restriction and school closures and has remained just above 1 during the stage 5 lockdown (Figure 4).



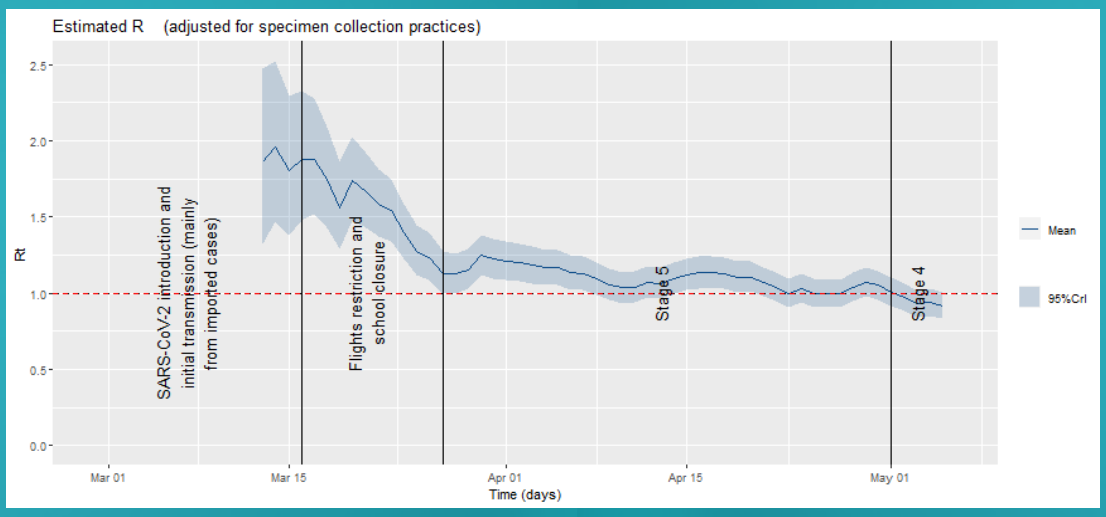
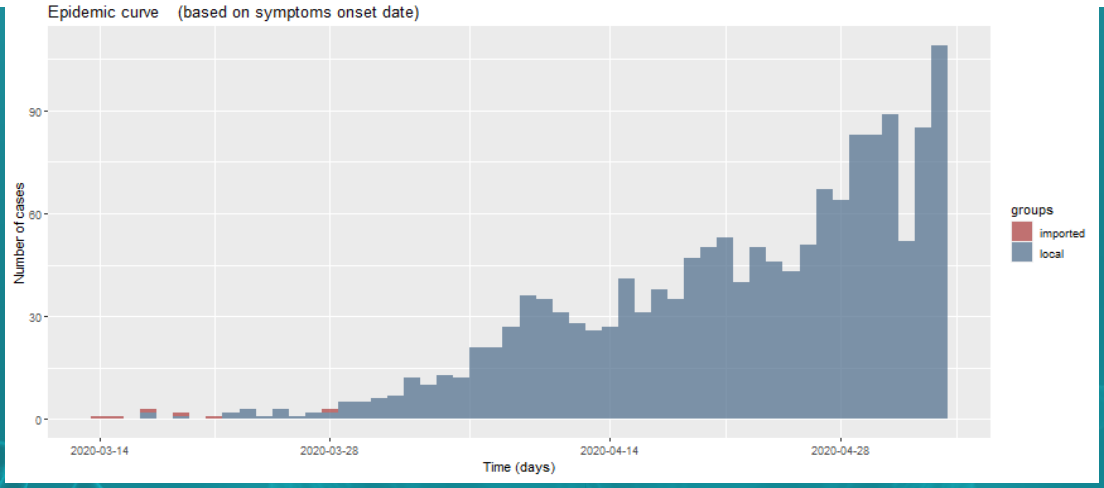


Figure 4. Gauteng (last date included in the estimation: 5 May 2020). Upper panel - Daily number of SARS-CoV-2 positive samples by date of symptom onset (missing data imputed). Lower panel - Estimated daily R adjusted for specimen collection practices

In Eastern Cape, the initial R (estimation period: 16 days from introduction) was 1.84 (95%CI: 1.10-2.84). The daily R has decreased from 2-2.5 to between 1 and 1.5 during the stage 5 lockdown (Figure 5).



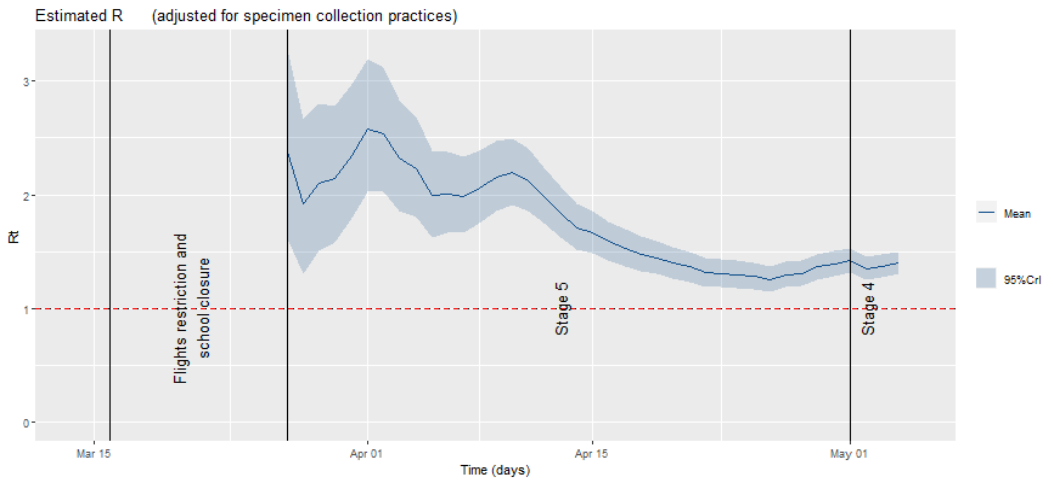
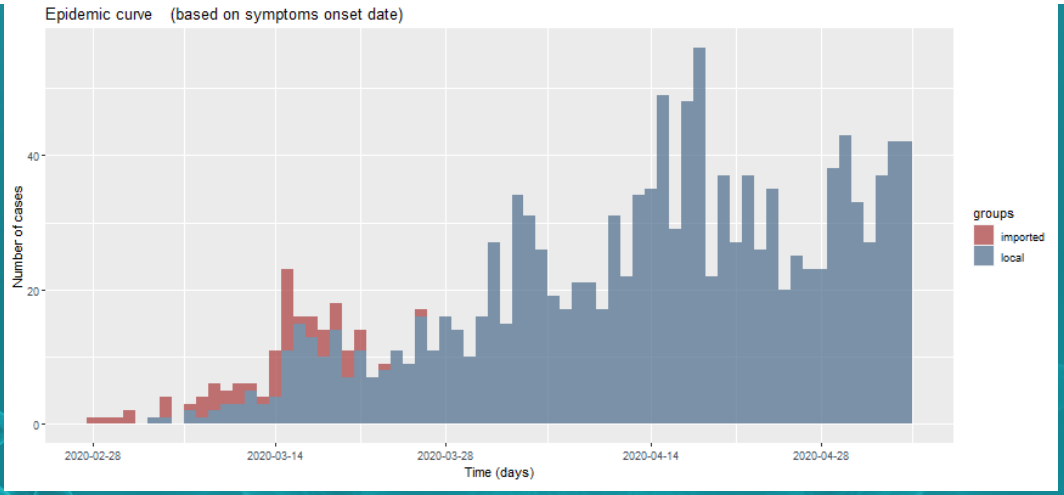


Figure 5. Eastern Cape (last date included in the estimation: 5 May 2020). Upper panel - Daily number of SARS-CoV-2 positive samples by date of symptom onset (missing data imputed). Lower panel - Estimated daily R adjusted for specimen collection practices

In KwaZulu-Natal, the initial R (estimation period: 16 days from introduction) was 1.73 (95%CI: 1.15-2.47) with transmission mainly from imported cases. The daily R dropped substantially during the period of flight restriction and school closures and has remained between 1 and 1.5 during the stage 5 lockdown (Figure 6).



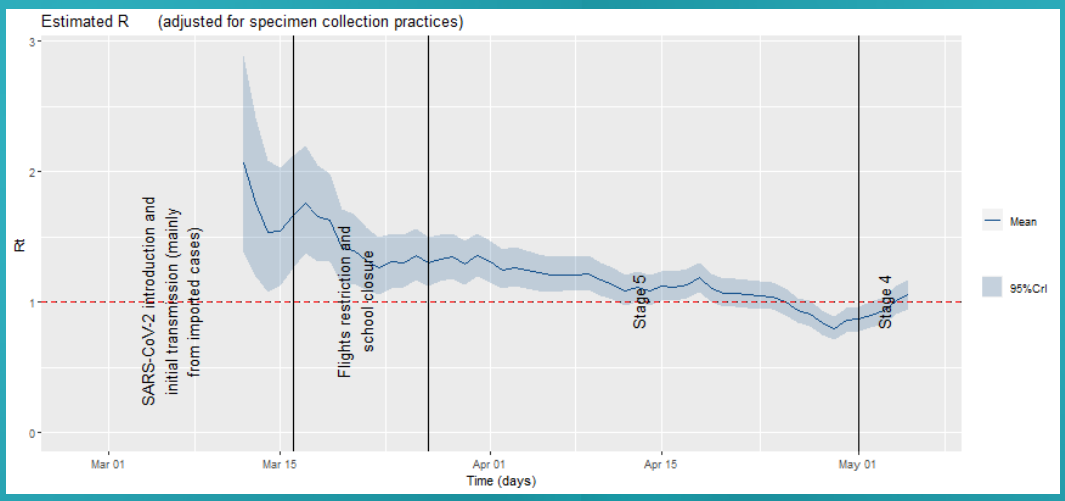


Figure 6. KwaZulu-Natal (last date included in the estimation: 5 May 2020). Upper panel - Daily number of SARS-CoV-2 positive samples by date of symptom onset (missing data imputed). Lower panel - Estimated daily R adjusted for specimen collection practices

INTERPRETATION

The initial R following introduction of imported cases was estimated between 1.7-2.5 (estimation period: 19 days from introduction) reflecting early transmission mainly from travellers into South Africa. The flight restrictions and school closures followed by level 5 lockdown appears to have substantially reduced the R, likely contributing to substantial flattening of the epidemic curve. While transmission has been slowed, R remained above 1, indicating ongoing transmission.

In the Western Cape Province the R remains around 1.5 reflecting ongoing raising of the epidemic. In other provinces, the R remains between 1 and 1.5 reflecting ongoing raising of the epidemic but at a reduced rate. Further lifting of the lockdown may be associated with increases in R in different provinces. Importantly, changes in rate of reporting and case definitions for testing may change over time potentially affecting R estimation. While we attempted to adjust for changes in testing practice, residual bias may remain. Therefore it is important to interpret these findings together with data on testing and other sources of data on transmission. In addition, caution should be exercised in interpreting comparisons between different time points and provinces as these could be affected by differential testing practices.

REFERENCES

I. White LF, Wallinga J, Finelli L, Reed C, Riley S, Lipsitch M, Pagano M. Estimation of the Reproductive Number and the Serial Interval in Early Phase of the 2009 Influenza A/H1N1 Pandemic in the USA. Influenza Other Respir Viruses. 2009 Nov;3(6):267-76. doi: 10.1111/j.1750-2659.2009.00106.x.

II. Archer BN, Tempia S, White LF, Pagano M, Cohen C. Reproductive number and serial interval of the first wave of influenza A(H1N1)pdm09 virus in South Africa. PLoS One. 2012;7(11):e49482. doi: 10.1371/journal.pone.0049482.

III. Wallinga J, Teunis P. Different Epidemic Curves for Severe Acute Respiratory Syndrome Reveal Similar Impacts of Control Measures. Am J Epidemiol. 2004;160(6):509-16. doi: 10.1093/aje/kwh255.

IV. White LF, Pagano M. A likelihood-based method for real-time estimation of the serial interval and reproductive number of an epidemic. Stat Med 2008; 27(16):2999–3016.

Data Source

National Institute for Communicable Diseases, COVID-19 Response Team

Contact

Prof Cheryl Cohen
cherylc@nicd.ac.za