Monitoring COVID-19 where capacity for testing is limited: use of a three-step analysis based on test positivity ratio

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Abstract
In an effort to monitor coronavirus disease 2019 (COVID-19), many countries have been calculating the ratio of cases confirmed to tests performed (test positivity ratio – TPR). While inferior to sentinel surveillance, TPR has the benefit of being easily calculated using readily available data; however, interpreting TPR and its trends can be complex because both the numerator and the denominator are constantly changing. We describe a three-step process where the ratio of relative increase in cases to relative increase in tests is accounted for in an adjusted TPR. This adjusted value more appropriately reflects the case number and factors out the effect of changes in the number of tests done. Unadjusted and adjusted TPRs are then assessed step-wise with reference to the epidemic curve and the cumulative numbers of cases and tests. Use of this three-step analysis and its potential use in guiding public health interventions are demonstrated for selected countries and subnational areas of the World Health Organization South-East Asia Region, together with the Republic of Korea as a reference. To date, application of the three-step analysis to data from countries of the region has signalled potential inadequacies of testing strategies. Further work is needed on approaches to support countries where testing capacity is likely to remain constrained. One example would be enumeration of the average number of tests needed to detect one COVID-19 case, which could be stratified by factors such as location and population. Such data would allow evidence-informed strategies that best balance the highest detection rate with the prevailing testing capacity.

Keywords: COVID-19, laboratory testing, test positivity ratio

Background
On 11 March 2020, the World Health Organization (WHO) declared coronavirus disease 2019 (COVID-19) a pandemic.¹ By mid-June 2020, while the status of the COVID-19 epidemics in other WHO regions appeared to be post-peak, the numbers of cases were still rising in the Americas, African and South-East Asia regions.² Countries of the WHO South-East Asia Region have been actively engaged in increasing capacity for laboratory testing for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), and most have publicly released daily numbers of tests performed.³ However, there have been vast differences among countries in the reported number of tests done per capita. Reasons include differences in individual countries’ epidemiological situations, infrastructures, resources, supply chains and availability of testing equipment. This deficit in testing capacity in the region, which mirrors the global shortage, is expected to remain a major challenge in the months ahead.⁴ This will further hinder countries’ ability to estimate the real incidence of COVID-19, which is indispensable to monitor the effectiveness of public health and social measures and implement changes to these measures with confidence.

Many countries have used laboratory data to calculate a test positivity ratio (TPR) and have used TPR trends to assess and compare their epidemic response performance with countries that are judged to have responded well, such as the Republic of Korea, and with those that are not.⁵ However, interpreting TPR and its trends can be complex because both the numerator and the denominator are constantly changing; to date, both the number of positive test results and the number of tests done have been increasing daily. Moreover, both values can be influenced independently by many factors. TPR characteristics depend on whether countries are in community transmission mode or at the beginning or end of an epidemic. In addition, low or high TPRs depend on many factors, such as the scale of transmission in the community, the testing strategy and consistency in its application, and implementation issues. Unless these factors are considered, TPR will not allow correct interpretation of the progression of an outbreak.

This paper describes a three-step analysis of TPR to monitor the progress of an outbreak and the quality of national
response. To demonstrate its utility, we apply this analysis to selected countries and two subnational areas of the WHO South-East Asia Region and, as a reference, to the Republic of Korea. The results should help optimize testing strategy and stimulate further work to improve outbreak response in countries where testing capacity is limited.

**Three-step analysis of test positivity ratio**

The analysis uses an “observed TPR” and an “adjusted TPR”.

**Observed TPR**

The observed TPR is derived from the daily data reports published on official websites and is calculated by dividing a day’s number of reported cases of COVID-19 by the number of tests for SARS-CoV-2 performed on the same date. This observed TPR differs from the actual TPR in that the denominator is the number of tests done, which will always be more than the number of suspected cases tested because a proportion of cases will be tested more than once. However, since all other factors are relatively constant, the observed TPR serves as a reasonable proxy for the real value.

**Adjusted TPR**

For the adjusted TPR, the daily observed TPR is multiplied by the daily ratio of increase in cases to increase in tests. The adjusted TPR on day t is the observed TPR on day t multiplied by the ratio of relative increase in cases on day t to the relative increase in tests on day t. The adjusted TPR therefore appropriately takes account of the influence of the numerator and factors out the effect of the denominator.

The adjusted TPR for day t is calculated as:

\[
\text{adjusted TPR}_t = \text{observed TPR}_t \times r_{case_t} / r_{test_t}
\]

The growth rates of cases and tests on day t, respectively, are calculated as:

\[
r_{case_t} = C_t - C_{t-1} / C_{t-1}, \text{ and } r_{test_t} = T_t - T_{t-1} / T_{t-1}
\]

In addition, increases in cases \((r_{case})\) and tests \((r_{test})\) that are exponential are calculated using the LOGEST function in Microsoft Excel.

**Examples of use of the three-step analysis**

Annex Fig. 1 shows graphs A, B, and C for the following countries/ states and time periods: 1. Thailand (13 January–3 June 2020); 2. Republic of Korea (31 December 2019–25 May 2020); 3. India (30 January–3 June 2020); 4. Maharashtra, India (5 April–4 June 2020); 5. Sri Lanka (28 January–3 June 2020); 6. Kerala, India (1 April–3 June 2020).

**First step:** The observed TPR trend (graphs A in Annex Fig. 1) is interpreted with reference to the epidemic curve. Observed TPR trends can be either relatively unchanged (graphs 3A, 4A, 6A) or follow the shape of the epidemic curve (graphs 1A, 2A, 5A). For the latter, the observed TPR trend appears to be a proxy for the trajectory of an epidemic, with lower rates at the beginning and end and higher rates at the peak.

**Second step:** The observed TPR is interpreted against cumulative cases and cumulative tests and the correlation between the two (graphs B in Annex Fig. 1). Correlation between cumulative cases and tests indicates the effect of the denominator, i.e. the increase in the number of cases is a result of increased testing (graphs 3B, 4B). Lack of correlation (i.e. logistic growth for cases versus exponential growth for tests, as seen in graphs 1B and 2B) indicates that the increase in cases is independent of the increase in tests done, provided that the testing strategy has not changed.

**Third step:** Both the observed TPR and the adjusted TPR are interpreted with reference to the epidemic curve. Since the adjusted TPR appropriately takes into account the influence of the numerator and has the effect of increasing or decreasing the observed TPR, an increasing adjusted TPR trend reliably reflects a true increase in cases relative to an increase in tests. Similarly, when the adjusted TPR is decreasing in accordance with the epidemic curve, this is a signal that the number of cases actually is declining. Any discordance between the adjusted TPR and the epidemic curve is then explained by factors such as a change in testing strategy. This is an especially useful indicator for monitoring the progress of an epidemic when the observed TPR is flat.

**Illustration of the three-step analysis**

The examples shown in Annex Fig. 1 and described below demonstrate the application of the three-step analysis of TPR and its potential use in guiding public health interventions.

**Outbreak and post-peak community transmission**

(1. Thailand and 2. Republic of Korea)

**Key trends:** The increase in cases (logistic) was independent of the increase in testing (exponential). The observed TPR trends followed the shape of the epidemic curve (graphs 1A, 2A). This was confirmed (graphs 1C and 2C) by the exaggerated adjusted TPR closely mirroring the epidemic curve. Note that, for Thailand, the number of tests corresponds to the reported number of patients under investigation and not the actual number of tests performed.

**Interpretation:** This was the expected trend in the adjusted TPR. This indicates that the testing strategy was consistently and effectively applied throughout the epidemic.
Likely community transmission or uncontrolled large and numerous clusters, at least in some subnational areas (3. India)

- **Key trends:** The observed TPR was relatively flat overall or decreasing during 1 April–5 May, while cases were increasing. From 6 May, the observed TPR started to increase steadily (graph 3A). The exponential growths in cumulative tests (10.3%) and cases (8.7%) were similar (graph 3B). After 6 May, TPR trends mirrored the epidemic curve, and the adjusted TPR increased faster than the observed TPR (graph 3C).
- **Interpretation:** The flat observed and adjusted TPRs up to 5 May are explained by the cumulative case trend mirroring that of tests, since the increase in the number of cases was mostly due to an increased number of tests. From 6 May onwards, the increase in the adjusted TPR mirrored the epidemic curve and reflected a significant change in testing strategy, shifting from a low-yield to a higher yield approach. This included, for example, the suspension of testing of asymptomatic cases and resulted in a higher case-detection rate.

Likely community transmission in a subnational area (4. Maharashtra, India)

- **Key trends:** Testing numbers increased and peaked around 29 May (graph 4A). The increase in the observed TPR was relatively uniform apart from a dip during 10–21 May (graph 4A). Cumulative tests and cases grew exponentially, not mirroring each other (different growth rates of 5.9% and 8.4%, respectively, graph 4B). The TPR trends matched the epidemic curve in multiple periods; the adjusted TPR trends significantly exaggerated the observed TPR trends while matching the epidemic curve during these periods (graph 4C).
- **Interpretation:** The testing strategy was responsive. However, variations in the adjusted TPR suggest there were inconsistencies in applying the testing strategy, as the number of cases increased steadily.

Clusters of cases in a country (5. Sri Lanka)

- **Key trends:** There was a steady increase in the number of tests performed (graph 5A). However, observed TPR trends were relatively unchanged (graph 5A). Cumulative tests and cases grew exponentially, but the curves do not match (graph 5B). Observed TPR trends matched the epidemic curve, with amplified adjusted TPR trends during the epidemic peaks (graph 5C).
- **Interpretation:** The testing strategy was consistently applied, with the adjusted TPR reflecting the epidemic curve.

Clusters of cases in a subnational area (6. Kerala, India)

- **Key trends:** TPR was low but mirrored the epidemic curve (graph 6A). Clusters of cases were the transmission pattern until a very large increase in cases at the end of May (graph 6A). Cumulative tests (3.7%) and cases (1.6%) grew exponentially but for limited periods (graph 6B). The observed TPR mostly reflected the epidemic curve; adjusted TPR trends exaggerated the effect of observed TPR trends, but more significantly from mid-May onwards (graph 6C).
- **Interpretation:** The testing strategy was consistently applied but skewed towards lower yield detection rates, indicating a possible need for strategy optimization to improve detection.

### Developing further tools to inform testing strategies in capacity-limited settings

The WHO Regional Office for South-East Asia has been using TPR and its trends as part of its obligation under the International Health Regulations, 2005, to monitor the epidemic in the region and for risk assessment purposes. WHO has produced guidance on reporting COVID-19 data and has recommended that countries also consider using existing hospital-based severe acute respiratory infection (SARI) and primary care influenza-like illness (ILI) sites, or whichever syndromic respiratory disease systems may already be in place for surveillance. Harnessing these sentinel surveillance data based on random sampling and testing of SARI and ILI cases to monitor the epidemic trajectory would indeed be very helpful. However, most countries in the WHO South-East Asia Region have had limited capacity to share this information with WHO with the timeliness that effective monitoring requires, since they have been overwhelmed with their COVID-19 response activities. Since the three-step analysis described in this paper uses data already available, it could be a useful complement to sentinel surveillance for COVID-19 to monitor the epidemic.

More importantly, the authors have been using TPR and trends to detect and raise questions on potential inconsistencies between data and their interpretation on the response performance. Use of the three-step analysis has allowed the WHO Regional Office for South-East Asia to engage national health authorities. An example was the instance of a consistently low TPR while cases rose in the context of community transmission, as shown in graph 3A. This situation was explained by a low-yield detection strategy combined with under-detection. As testing capacity had been limited, the regional office suggested that the health authorities should review their testing strategy and its implementation to shift from a low-yield to a higher yield strategy.

A major contribution of use of the three-step analysis in the region to date has been to signal potential inadequacies of testing strategies in settings in which testing capacity is limited. We therefore propose a review of testing strategies that allows a basic assessment and comparison of the average number of tests needed to detect one COVID-19 case. The review could assess how this yield effectiveness might be sustained for each country, in the light of projected testing needs and overall testing capacity. For individual countries, testing strategy could be further informed by assessing the yield effectiveness by category. First, especially for large countries, this would be by geographical location (e.g. by subnational level) and by type of transmission dynamics (i.e. no circulation, clusters of cases, community transmission). The estimates would then inform testing strategy in terms of the populations to be prioritized for testing. Second, yield effectiveness could be estimated and compared among population categories, such as asymptomatic cases, contacts, ILI cases, SARI cases, vulnerable populations and health-care workers.
As a caveat, seeking highest yield (i.e. the highest detection rates) could be misleading. For instance, mainly testing patients with SARI as community transmission is evidenced will increase yield, as these patients are more likely to have SARS-CoV-2 infection; however, cases with mild symptoms or that are asymptomatic may not be detected and the disease could consequently spread. A change in testing strategy runs the risk both of increasing and of decreasing case identification.

These data would allow evidence-informed discussion on the approach that best balances the highest detection rate with an acceptable number of tests needed; the approach would be based on feasibility and acceptability and would take into account limited testing capacity. Indeed, obtaining the highest sensitivity of detection would not be within the reach of countries of the region. In the context of this limited testing capacity, the WHO has recommended that testing is prioritized for people who meet the WHO criteria for a suspected COVID-19 case. In addition to increasing yield effectiveness, the priority is to identify and isolate patients with respiratory symptoms, who are more likely to transmit to others.

In conclusion, as testing and isolating many infected cases may not be achievable in capacity-limited settings, interrupting the chain of transmission must rely on substantial organization efforts and dedication to listing, tracing and quarantining all contacts. From the start of the epidemic, the WHO Health Emergencies Programme of the regional office has emphasized improving the quality of contact tracing as its primary objective when supporting Member States.

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References

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<th>Area</th>
<th>Observed TPR</th>
<th>Cumulative tests</th>
<th>Cumulative cases</th>
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<tr>
<td>A</td>
<td>25%</td>
<td>10,000</td>
<td>3500</td>
</tr>
<tr>
<td>B</td>
<td>25%</td>
<td>19,000</td>
<td>3000</td>
</tr>
<tr>
<td>C</td>
<td>20%</td>
<td>14,000</td>
<td>2500</td>
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New tests
16% 80
20% 80
14% 80
10% 80

New cases
15% 60
16% 60
18% 60
20% 60

\[\text{Observed (red)/adjusted (black) TPR}\]

Exponential growth in tests = 10.3% and in cases = 8.7%.

Exponential growth in tests = 3.7% and in cases = 1.6%.
Annex Fig. 1, continued  Three-step test positivity analysis applied to six geographical areas

TPR: test positivity ratio. Both observed and adjusted TPRs plotted as 7-day moving averages.

*For Thailand, the number of tests corresponds to the reported number of patients under investigation and not the actual number of tests performed.

Exponential growth in tests = 10.3% and in cases = 8.7%.
Exponential growth in tests = 5.9% and in cases = 8.4%.
Exponential growth in tests = 3.7% and in cases = 1.6%.