Average detection rate of SARS-CoV-2 infections is estimated around six percent

On March 31st, 2020, reported case fatality rates in the countries currently most affected by the novel coronavirus disease (COVID-19) ranged from 11.7% in Italy to 1.1% in Germany (a factor of 10.6),[1] suggesting vast differences in the quality of countries' case records. In particular, (confirmed) case fatality rates may only be a very poor proxy for the true infection fatality rate if a high number of infections remain undetected. Despite such uncertainties, policy makers rely heavily on the extrapolation of past trends when planning responses to the pandemic.

A recent study,[2] combining data from mainland China with those of international Wuhan residents returning on repatriation flights, presented novel age-specific estimates for the infection fatality rate. As returning Wuhan expats have been subject to extensive testing, substantial underdiagnosing is unlikely, providing confidence in these numbers. We therefore treat the reported infection fatality rates as benchmark for other countries and calculate infection fatality rates for the 40 most affected countries using UN population data to correct for differences in age distributions (see Table 1).[3] The same study estimates the average time from symptom onset to death to be approximately 18 days.[2] If we conservatively assume that individuals are tested four days after symptom onset and if countries were successful in tracing the majority of infections, dividing the cumulative number of deaths on March 31st by the cumulative number of confirmed cases by March 17th should yield case fatality rates similar to the reported infection fatality rates. This is, however, generally not the case. Instead, in all countries, the number of confirmed cases by March 17th was substantially lower than what would have been expected given the total number of deaths reported two weeks later. The average detection rate is around six percent, making the number of cases that is reported in the news on a daily basis rather meaningless. To estimate the true number of infections on March 31st, we assume for simplicity that detection rates are constant over time. We believe that this is on average a rather conservative assumption as it is getting more difficult in a growing pandemic to detect all cases despite huge efforts to increase testing capacity. Countries that started with a very low detection rate like Turkey or even the United States might be an exception to this. We calculate the estimated number of infections on March 31st dividing the number of confirmed cases on March 31st by the detection rate. While the Johns Hopkins data report less than a million confirmed cases globally at the moment this correspondence is written, we estimate the number of infections to be a few tens of millions.

Putting an end to current travel restrictions and social distancing measures will not only require a strong reduction in the transmission of new cases but also major improvements in the ability of countries to detect new infections to then adopt adequate measures for isolating infected patients and tracing potential contact persons. In absence of such measures, the virus might remain undetected again for an extended period of time and a new outbreak is likely just a matter of time.

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We have no competing interests.

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Table 1: Country records of COVID-19 deaths, number of confirmed cases and estimated number of infections

Country	Infection fatality rate	Number of deaths (March 31st)	Number of confirmed cases (March 17th)	Estimated number of infections (March 17th)	Estimated detection rate	Number of confirmed cases (March 31st)	Estimated number of infections (March 31st)	Share of population infected (March 31st)
Italy	1.38%	12,428	31,506	899,426	3.50%	105,792	3,020,125	5.00%
Spain	1.21%	8,464	11,748	701,030	1.68%	95,923	5,723,946	12.24%
US	0.96%	3,873	6,421	404,390	1.59%	188,172	11,850,950	3.58%
France	1.20%	3,532	7,715	294,205	2.62%	52,827	2,014,513	3.09%
Iran	0.43%	2,898	16,169	672,755	2.40%	44,605	1,855,912	2.21%
UK	1.09%	1,793	1,960	164,727	1.19%	25,481	2,141,529	3.15%
Netherlands	1.14%	1,040	1,711	91,126	1.88%	12,667	674,628	3.94%
Germany	1.30%	775	9,257	59,407	15.58%	71,808	460,828	0.55%
Belgium	1.14%	705	1,243	62,019	2.00%	12,775	637,402	5.50%
Switzerland	1.13%	433	2,700	38,229	7.06%	16,605	235,107	2.72%
Turkey	0.55%	214	47	38,770	0.12%	13,531	11,161,684	13.23%
Brazil	0.59%	201	321	33,848	0.95%	5,717	602,838	0.28%
Sweden	1.15%	180	1,190	15,601	7.63%	4,435	58,142	0.58%
South Korea	0.96%	162	8,320	16,818	49.47%	9,786	19,782	0.04%
Portugal	1.32%	160	448	12,123	3.70%	7,443	201,415	1.98%
Indonesia	0.42%	136	172	32,694	0.53%	1,528	290,445	0.11%
Austria	1.15%	128	1,332	11,129	11.97%	10,180	85,052	0.94%
Canada	1.05%	101	478	9,651	4.95%	8,527	172,170	0.46%
Denmark	1.14%	90	1,025	7,912	12.95%	3,039	23,459	0.41%
Philippines	0.36%	88	187	24,457	0.76%	2,084	272,557	0.25%
Romania	1.09%	82	184	7,525	2.45%	2,245	91,819	0.48%
Ecuador	0.47%	75	58	15,809	0.37%	2,240	610,563	3.46%
Ireland	0.84%	71	223	8,469	2.63%	3,235	122,852	2.49%
Japan	1.60%	56	878	3,490	25.16%	1,953	7,762	0.01%
Domin. Rep.	0.48%	51	21	10,621	0.20%	1,109	560,915	5.17%
Iraq	0.23%	50	154	21,858	0.70%	694	98,502	0.24%
Greece	1.34%	49	387	3,660	10.57%	1,314	12,428	0.12%
Egypt	0.34%	46	196	13,423	1.46%	710	48,625	0.05%
Algeria	0.43%	44	60	10,323	0.58%	716	123,187	0.28%
Malaysia	0.45%	43	673	9,495	7.09%	2,766	39,024	0.12%
Norway	1.01%	39	1,463	3,874	37.76%	4,641	12,290	0.23%
Morocco	0.47%	36	38	7,589	0.50%	617	123,227	0.33%
India	0.41%	35	142	8,462	1.68%	1,397	83,250	0.01%
Poland	1.06%	33	238	3,101	7.68%	2,311	30,110	0.08%
Czechia	1.09%	31	396	2,837	13.96%	3,308	23,696	0.22%
Peru	0.54%	30	117	5,585	2.09%	1,065	50,839	0.15%
Panama	0.54%	30	69	5,551	1.24%	1,181	95,016	2.20%
Mexico	0.48%	28	82	5,777	1.42%	1,094	77,079	0.06%
Argentina	0.67%	27	68	4,024	1.69%	1,054	62,367	0.14%
Pakistan	0.29%	26	236	8,911	2.65%	1,938	73,173	0.03%

Note: The infection fatality rate is calculated as weighted sum of the age specific infection fatality rates from Verity et al. (2020) weighted by the population shares of each age group from the United Nations population data. The estimated number of infections on March 17th is the number of deaths on March 31st divided by the infection fatality rate. The estimated detection rate is the number of confirmed cases divided by the estimated number of infections on March 17th. The estimated number of infections on March 31st is the number of confirmed cases on March 31st divided by the estimated detection rate.

Update (April 9th, 2020)

In the following, we would like to explain some limitations and assumptions of our estimates in response to questions we received from readers:

- We use the estimates of Verity et al. (2020) for infection fatality rates to estimate expected infection fatality rates for other countries adjusting for difference in age structure. Countries also differ in other important characteristics such as prevalence of pre-existing conditions, quality and capacity of the health system and phase of the epidemic they are in. The true infection fatality rates could therefore differ from our estimates. For instance, it is possible that countries with very good health systems are more successful in treating patients than China. As a consequence, the reported number of deaths would correspond to a higher number of overall infections and result in a lower-than-expected detection rate. However, in absence of better data from serological studies that would be able to incorporate such differences, we rely on this simplifying assumption.
- We assume a constant detection rate between March 17th and March 31st. If social distancing measures actually work, the detection rate will likely go up, because few new infections emerge and the health system has an opportunity to catch up on the infections that were previously missed. On the other hand, it gets more and more difficult to detect infections if many new infections occur. Readers should therefore exercise caution when extrapolating detection rates far to the future.
- We assume that the expected time to death is the same for all countries as reported in Verity et al. (2020) and that four days pass from first symptoms until a case is tested and confirmed positive. A longer survival time would imply even lower detection rates and while shorter survival times would lead to higher rates.
- Estimates with fewer assumptions will become possible once large-scale population-representative serology antibody studies have become available.
- There is some confusion in the public debate between case fatality and infection fatality rates. Case fatality rates only represent the fraction of lethal outcomes among those who have tested positive, while infection fatality rates also include undiagnosed infections. In addition, case fatality rates based on the current cumulative numbers of deaths and confirmed cases are misleading, because time from infection to death is rather long. Current deaths are a consequence of infections that happened on average more than two weeks in the past.