Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

expanded, an asymptomatic patient infected 1 week before testing positive on March 3 should, but will not, be included in calculations for March 16.

For the stated purpose of the authors, it might be useful to also include everyone who was symptomatic for 14 days before the calculated date. Consider a CFR calculation for March 15. If an individual was symptomatic on March 1 and tested positive on March 10, they would not be included in the denominator, even though the patient probably contracted the disease before the 14-day lag time.

Moreover, patients with mild symptoms might not undergo testing and so might not be included in the overall denominator. A further consideration is the delay between testing and receipt of results. Consequently, individuals might not test positive until after the suggested 14-day incubation period. With disease spread, indications for COVID-19 testing will expand, thereby increasing the denominator size. These factors might act as time-varying confounding variables in the authors' calculation of CFR.

One other published lag-time calculation has included half the additional cumulative deaths in the numerator and time from illness to death as the lag-time (13 days).[3] For example, if calculating the CFR for March 15, the denominator would be cumulative cases until March 2, and the numerator would be cumulative deaths until March 2, in addition to half of the deaths recorded from March 2–15. This method assumes a normal distribution of time from illness to death.

Although underestimation of CFRs risks the population not taking the threat seriously, overestimation might lead to unnecessary additional panic and concern. During a rapidly evolving pandemic, accurate measures of disease characterisation are important. Future estimates will probably involve patient-specific data for refined calculation. However, the provided CFR estimate of 15·2% for countries outside China might be a premature statistic owing to the limitations of their methods.

We declare no competing interests.

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We congratulate David Baud and colleagues[1] for their apt observations regarding the burden of the coronavirus disease 2019 (COVID-19) epidemic and the possibly higher than expected proportion of cases that are fatal. Precision, however, is as necessary in calculations as in semantics.

According to the *Dictionary of Epidemiology*, the mortality rate is an "estimate of the portion of a population that dies during a specified period".[2] In the case of this outbreak, the mortality rate over a period of 1 year per 100 000 Chinese citizens would be around 0·23 (as of March 16, 2020). Therefore, precisely speaking, neither older estimates nor Baud and colleagues' new calculation can be referred to as the mortality rate.

In both trade press and newspapers, the case fatality rate (CFR) is often used to describe the situation pertaining to COVID-19, as well as to any other epidemic. The definition of the CFR in the *Dictionary of Epidemiology* states that it is "the proportion of cases of a specified condition that are fatal within a specified time".[2] On the one hand, as accurately pointed out by Baud and colleagues, the CFR might be underestimated because of a type of time-lag bias associated with diagnosing and reporting cases. Furthermore, calculations are based on the questionable assumption that all cases are being tested. On the other hand, as Pueyo suggests,[3] the CFR might be overestimated due to the definition of a case. During an epidemic, cases might be defined either as total cases (ie, every confirmed case) or as closed cases (ie, only those who have recovered or died). Hence, the denominator for the CFR might be either of these numbers. In the initial phase of the epidemic, the number of closed cases is relatively small, and so the CFR calculated per closed cases is an overestimate. By contrast, when the CFR is calculated per total cases, the numerator is underestimated, and thus the whole calculation becomes an underestimate.

Baud and colleagues' calculation, although interesting, is biased as well. As shown in the figure, it vastly overestimates the fatality of COVID-19 if one uses data from the initial phase of the outbreak. This overestimation is obviously due to undertesting and a time-lag bias, which is more pronounced in the beginning of an outbreak. As demonstrated in the figure, irrespective of the method used, all calculations are biased, especially in the initial part of an outbreak, and converge once all cases are closed. Nevertheless, it seems that the CFR calculated per total cases is the least affected by reporting biases.

As of March 16, the CFR per total cases in China is 4·00%, per closed cases is 4·44%, and as calculated with Baud and colleagues' method is 4·03%. However, despite the downturn of the outbreak in China,

8043 cases are still open, of which 2622 are serious or critical. According to Wu and McGoogan's estimates based on 72 314 cases from Wuhan,[4] 81% of patients are classified as mild, 14% as severe, and 5% as critical. CFRs in these subgroups are 0%, 0%, and 49%, respectively. Based on these estimates, of 8043 open cases in China, about 377 are in a critical condition and of those 184 will die. Therefore, once all active cases are closed, we might expect the CFR in China to be around 3·85%.

On a technical note, Baud and colleagues' calculation seems to be an attempt at reporting the cumulative death rate, which is defined as "the proportion of a group that dies over a specified time", rather than the mortality rate.[2]

In summary, the CFR calculated per total cases seems to remain the best tool to express the fatality of the disease, even though it might underestimate this figure in the initial phase of an outbreak.

All calculations were based on data acquired from worldometer.info/coronavirus and are available in the appendix. We declare no competing interests.

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In their Correspondence, David Baud and colleagues[1] suggest that case fatality rates (CFRs) for coronavirus disease 2019 have been underestimated and propose to divide deaths at time *t* by cases at time *t* minus 14 days to correct this underestimation and provide so-called real estimates. Many biases in both directions afflict CFR estimates during outbreaks,[2] and experts have spent 2 decades (since the outbreak of severe acute respiratory syndrome coronavirus) finding ways to overcome these.[3] The delay problem highlighted by Baud and colleagues produces falsely low estimates, whereas the under-ascertainment of mild cases produces falsely high estimates.[4] These issues are well appreciated in the field and have been discussed in the popular press in recent weeks.[5,6]

No expert thinks the 3·6% raw ratio of deaths to cases on March 1 is an accurate estimate of the CFR because it suffers from all of these biases. The authors make the situation worse: correcting for delay (with an invalid method) without correcting for ascertainment of mild cases inflates the estimates, bringing them further from what most experts believe are the true numbers, around the 1–2% range for symptomatic cases.[7,8]

Baud and colleagues' estimates are not real; they are in fact less real than the biased calculations they claim to correct. Especially in a time of great urgency, authors have a responsibility to read and understand relevant background literature and look for obvious flaws in their own analysis. This work does not appear to have met that standard. The fact that peer review did not pick up these flaws should be a caution against hastening the peer review process at the expense of due care.

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Authors' reply

We thank David Dongkyung Kim and Akash Goel,[1] Piotr Spychalski and colleagues,[2] and Marc Lipsitch[3] for their critical reading of our Correspondence.[4] In response to the points raised regarding our statistical methods, we agree that our model might not be appropriate for the early epidemic period because of the rapid increase in the number of cases in the 14 days preceding reported deaths. During this period, many patients were certainly diagnosed with coronavirus disease 2019 (COVID-19) at the time they developed critical illness or even at the time of death. By contrast, asymptomatic patients and those with mild disease remained untested. These two factors probably explain the overestimates of mortality at the beginning of the curve (Feb 12–24 in our model,[4] as exemplified in the appendix).

As mentioned by Spychalski and colleagues, "irrespective of the method used, all calculations are

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See **Online** for appendix

See **Online** for appendix