THE UNIVERSITY OF MELBOURNE

Bloomberg Philanthropies

DATA FOR HEALTH INITIATIVE

# CRVS best-practice and advocacy

## Approaches and methods for estimating excess deaths due to COVID-19

June 2020

## Resources available from the University of Melbourne, Bloomberg Philanthropies Data for Health Initiative

*CRVS course prospectuses*
These resources outline the context, training approach, course content and course objectives for the suite of CRVS trainings delivered through the Bloomberg Philanthropies Data for Health Initiative. Each course focuses on a specific CRVS intervention or concept, and is designed to support countries to strengthen their CRVS systems and data.

*CRVS Fellowship reports and profiles*
The CRVS Fellowship Program aims to build technical capacity in both individuals and institutions to enhance the quality, sustainability and health policy utility of CRVS systems in Fellows' home countries. *Fellowship reports* are written by Fellows as a component of the program, and document, in detail, the research outcomes of their Fellowship. *Fellowship profiles* provide a summary of Fellows' country context in relation to CRVS, an overview of the Fellowship experiences, the research topic and the projected impact of findings.

*CRVS analyses and evaluations*
These analytical and evaluative resources, generated through the Initiative, form a concise and accessible knowledge-base of outcomes and lessons learnt from CRVS initiatives and interventions. They report on works in progress, particularly for large or complex technical initiatives, and on specific components of projects that may be of more immediate relevance to stakeholders. These resources have a strong empirical focus, and are intended to provide evidence to assist planning and monitoring of in-country CRVS technical initiatives and other projects

*CRVS best-practice and advocacy*
Generated through the Initiative, CRVS best-practice and advocacy resources are based on a combination of technical knowledge, country experiences and scientific literature. These resources are intended to stimulate debate and ideas for in-country CRVS policy, planning, and capacity building, and promote the adoption of best-practice to strengthen CRVS systems worldwide.

*CRVS country reports*
CRVS country reports describe the capacity-building experiences and successes of strengthening CRVS systems in partner countries. These resources describe the state of CRVS systems-improvement and lessons learnt, and provide a baseline for comparison over time and between countries.

*CRVS technical guides*
Specific, technical and instructive resources in the form of *quick reference guides, user guides* and *action guides*. These guides provide a succinct overview and/or instructions for the implementation or operation of a specific CRVS-related intervention or tool.

*CRVS tools*
Interactive and practical resources designed to influence and align CRVS processes with established international or best-practice standards. These resources, which are used extensively in the Initiative's training courses, aim to change practice and ensure countries benefit from such changes by developing critical CRVS capacity among technical officers and ministries.

Published by the University of Melbourne, Civil Registration and Vital Statistics Improvement, Bloomberg Philanthropies Data for Health Initiative.

Melbourne School of Population and Global Health
Building 379
207 Bouverie Street
Carlton, VIC 3053
Australia

CRVS-info@unimelb.edu.au
www.mspgh.unimelb.edu.au/dataforhealth

**Made possible through funding from Bloomberg Philanthropies**
**www.bloomberg.org**

**Suggested citation**

Adair, T, Lopez, AD, Hudson, S. *Approaches and methods for estimating excess deaths due to COVID-19*. CRVS best-practice and advocacy. Melbourne, Australia: Bloomberg Philanthropies Data for Health Initiative, Civil Registration and Vital Statistics Improvement, University of Melbourne; 2020.

# Contents

# Approaches and methods for estimating excess deaths due to COVID-19

This guidance document outlines the challenges, and introduces approaches and methods for researchers and statisticians to measure excess mortality due to COVID-19 in systems with various levels of death registration completeness (high, medium and low completeness levels). For additional COVID-19 resources, visit: https://crvsgateway.info/Responding-to-COVID-19

## Introduction

In December 2019, an outbreak of a respiratory disease associated with a novel coronavirus was reported in the city of Wuhan, Hubei Province, Republic of China. The virus spread worldwide, and on March 11, 2020, the World Health Organization (WHO) declared coronavirus disease 2019 (COVID-19) a pandemic.[1] Globally, countries have recognised the COVID-19 pandemic as a public health emergency. In a public health emergency, mortality surveillance is extremely important to monitor disease progression in the population and assess the impact of interventions since it can provide recent evidence on the impact of the epidemic through established data collection and compilation mechanisms, particularly CRVS systems.

## Cause specific, or all-cause mortality as a measure for COVID-19?

Typically, public health intervention strategies are cause-specific and hence require the input of accurate, cause-specific mortality data for major diseases or injuries (such as lung cancer, HIV/AIDS, road traffic accidents etc.) to asses and monitor impact. The same is true for action to control COVID-19. Obtaining accurate cause-specific data to measure mortality due to COVID-19, however, has been challenging for several key reasons.

Firstly, diagnostic uncertainty could lead to a miscount of COVID-19 deaths. Despite global certification and coding standards established by the World Health Organization (WHO) for COVID-19, physicians and coders currently have limited experience in certifying and coding these deaths. Diagnostic uncertainty is further compounded by the age of decedents, with COVID-19 mortality concentrated among the elderly.[2] Multiple co-morbidities are often experienced at older ages, making it difficult for certifiers and coders to understand, and thus report, the causal chain leading to death. Diagnostic uncertainty may also be compounded in populations where testing rates are low.

Secondly, categorical attribution of a COVID-19 infection does not necessarily tell the complete public health story. Evidence suggests that infection increases mortality risk from a number of other conditions, including coronary artery disease, heart failure, cardiac arrhythmias and, particularly, chronic obstructive pulmonary disease.[3,4] Further,the effects of social isolation mandates may, for example, inadvertently increase the risk of deaths from suicide and domestic violence, yet simultaneously but conversely, decrease the risk of mortality from road traffic accidents and acute respiratory disease due to reduced air pollution.[5,6,7] COVID-19 may therefore be impacting mortality in both positive and (likely predominantly) negative ways, with the net contribution of this yet to be understood.

1 The World Health Organization. *Coronavirus disease (COVID-19) outbreak*. 2020. Available at: https://www.who.int/westernpacific/emergencies/covid-19

2 The World Health Organization. Report of the WHO-China Joint Mission on Coronavirus Disease 2019 (COVID-19). The World Health Organization, February 2020. Available at: http://www.who.int/docs/default-source/coronaviruse/who-china-joint-mission-on-covid-19-final-report.pdf

3 Klok, FA, Kruip, MJHA, van der Meer, NJM, Arbous, MS, Gommers, DAMPJ, Kant, KM, Kaptein, FHJ, van Paassen, J, Huisman, MV, Endeman, H. 'Incidence of thrombotic complications in critically ill ICU patients with COVID-19'. Thrombosis Research. July 2020. 191:145-147. Available at: https://doi.org/10.1016/j.thromres.2020.04.013

4 Long, B, Brady, W, Koyfman, A, Gottlieb, M. 'Cardiovascular complications in COVID-19'. *American Journal of Emergency Medicine*. April 2020. Available at: https://doi.org/10.1016/j.ajem.2020.04.048

5 The World Health Organization. *Mental health and COVID-19*. 2020. Available at: http://www.euro.who.int/en/health-topics/health-emergencies/coronavirus-covid-19/technical-guidance/mental-health-and-covid-19

6 The World Health Organization. *The rise and rise of interpersonal violence – an unintended impact of the COVID-19 response on families*. 2020. Available at: http://www.euro.who.int/en/health-topics/health-emergencies/coronavirus-covid-19/news/news/2020/6/the-rise-and-rise-of-interpersonal-violence-an-unintended-impact-of-the-covid-19-response-on-families

7 Chen, K, Wang, M, Huang, C, Kinney, P, Anastas, P. *Air pollution reduction and mortality benefit during the COVID-19 outbreak in China*. The Lancet, Planetary Health. May 2020. Available at: https://doi.org/10.1016/S2542-5196(20)30107-8

Thirdly, the increased strain on health care services during the pandemic may lead to increased mortality from other conditions or injuries. With vital health care resources, including ICU beds, being diverted away from the acute care previously afforded for emergency treatment of heart attacks and strokes, or trauma victims, for example, or with large reductions in routine procedures such as cancer screening due to prioritising COVID-19 diagnosis and treatment, many people may not be receiving urgent medical attention for life-threatening conditions that they otherwise would have. It is also possible that patients who need care might be actively avoiding health services altogether due to a fear of contracting COVID-19, even in the presence of serious conditions requiring emergency hospitalisation or medical treatment.[8]

Finally, the challenge of diagnosing COVID-19 deaths outside of hospitals presents a significant barrier to obtaining accurate cause-specific mortality data. Most COVID-19 mortality data come from hospitals, however, with the majority of deaths in low- to middle-income countries occurring outside of health facilities,[9] COVID-19 is likely to be substantially underreported since community deaths are generally poorly captured by vital registration systems in these countries. Further, deaths in aged-care facilities must also be counted in addition to hospital and community deaths. Given the strong age-dependency of COVID-19 deaths, with the vast majority occurring among people aged 70 and above, omitting these deaths from the count of COVID-19 cases is likely to severely underestimate the impact of the pandemic. Indeed, when community and aged-care facility deaths are included, the death toll from COVID-19 can increase by 50 to 100 per cent, as seen in the United Kingdom, Wuhan and elsewhere.[10]

Due to the complexities inherent in obtaining accurate cause-specific data, all-cause mortality is a much better way of assessing the impact of COVID-19, as it captures the net effect of all factors that may increase or decrease mortality, and is readily measureable from existing CRVS systems. Further, all-cause mortality is preferable to case-fatality measures, given the likelihood of missed or ill-attributed COVID-19 cases. In the absence of mortality shocks (e.g. earthquakes), the age-specific all-cause mortality rate helps to avoid measurement biases and is, therefore, the most reliable and comprehensive measure of the overall impact of COVID-19 in a population. All-cause mortality allows us to understand how many additional deaths occurred because of (and not just 'due to') the presence of COVID-19 and thus provides a more complete and comprehensive measure of the impact of the pandemic than the COVID-19 cause-specific death rate or the case-fatality rate.

In order to measure all-cause mortality, an estimation of excess deaths within a population is required. This requires data on the number of deaths that occurred, by age and sex, from a vital registration system (the numerator) as well as the size of the population exposed to risk of dying, also by age and sex (the denominator). In most countries, recent population data disaggregated by age, sex and location, are available either from a recent population census, or from demographic projections made by the national statistics office. The challenge for countries is to reliably measure the all-cause mortality rate through either a complete death registration system, or by applying knowledge about the completeness of death registration to incomplete mortality data. Detailed guidance on how to do this is provided in the following sections.

8 Jennings, G. *COVID, ACE inhibitors/ARBs, and cardiovascular diseases*. The Medical Journal of Australia. April 2020. Available at: https://www.mja.com.au/journal/2020/covid-ace-inhibitorsarbs-and-cardiovascular-diseases

9 de Savigny, D, Riley, I, Chandramohan, D, et al. *Integrating community-based verbal autopsy into civil registration and vital statistics (CRVS): system-level considerations*. Global Health Action, Vol. 10(1), 2017. Available at: https://doi.org/10.1080/16549716.2017.1272882

10 The Economist. Tracking covid-19 excess deaths across countries. 27 May 2020. Available at: https://www.economist.com/graphic-detail/2020/04/16/tracking-covid-19-excess-deaths-across-countries

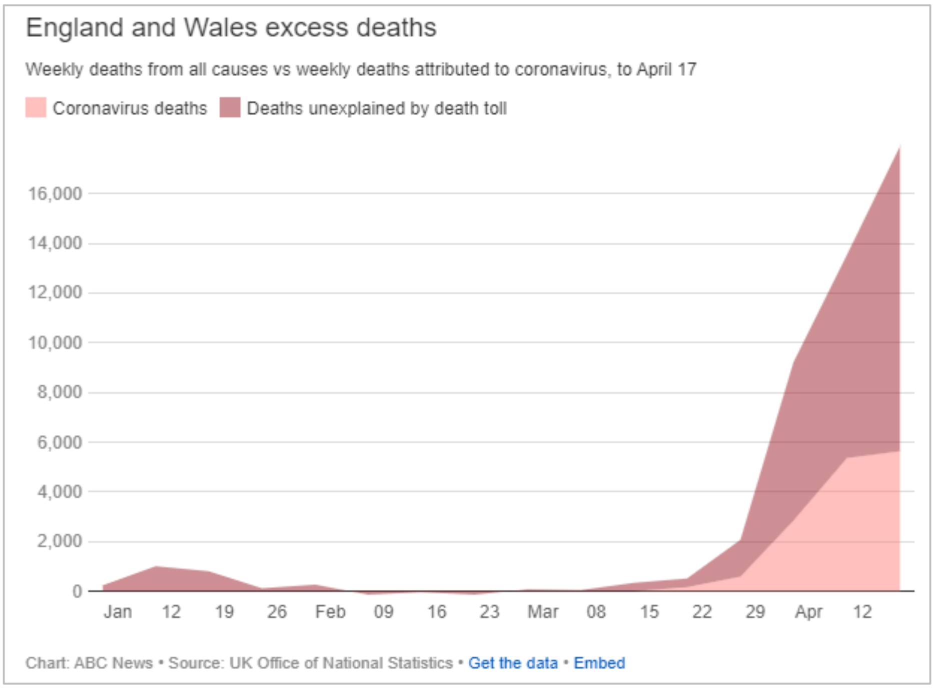
## Introduction to excess mortality

Excess mortality, as it pertains to COVID-19, is defined as the number of deaths reported (or estimated) to have occurred during the COVID-19 pandemic, in excess of the number of deaths that would have been expected to have occurred during the same period, based on past trends. It is important to note that excess deaths are not precisely defined by the number of deaths where COVID-19 is the cause, other factors influence this.

*Excess mortality = Reported (estimated) deaths – Expected deaths*

The utility of timely and complete death registration systems to measure excess mortality is demonstrated in the following two examples (**Figures 1** and **2**). The first example from England and Wales (**Figure 1**) shows weekly excess mortality from January to April 2020, with the number of excess deaths apportioned between deaths where COVID-19 is the reported cause and all other deaths. In the last week reported, approximately two-thirds of excess deaths have a cause that is not COVID-19. This demonstrates how analysis of excess mortality will provide a more comprehensive picture of the impact of COVID-19 than just relying on the reporting of COVID-19 as a cause of death.

**Figure 1: England and Wales, excess deaths from all causes versus deaths attributed to COVID-19**

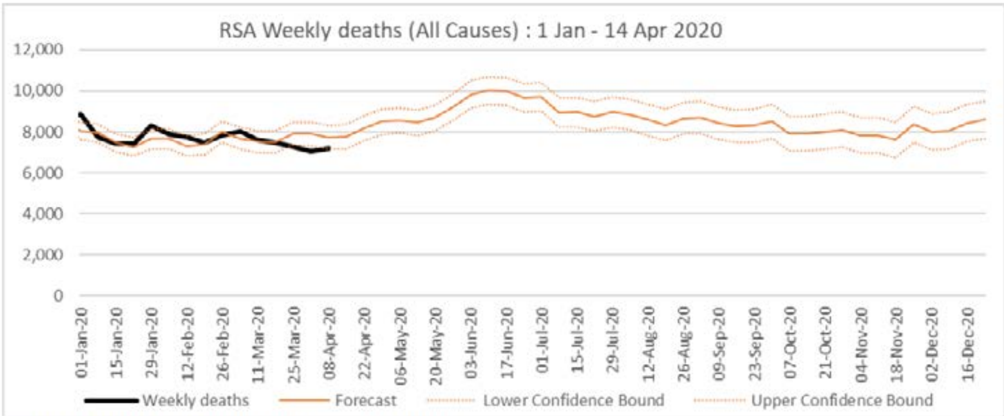



Source: ABC News. https://www.abc.net.au/news/2020-04-30/coronavirus-deaths-likely-higher-due-to-excess-deaths/12200850

Another example of measuring excess deaths is from South Africa (**Figure 2**). Again, in this example, reported weekly deaths (shown by the black line) are compared to forecasted expected deaths (shown by the unbroken orange line). This graph also shows 95 per cent confidence intervals around the expected deaths. These confidence intervals represent the range within which there is 95 per cent likelihood that the true number of expected deaths will lie. This range exists because of random variation in the number of deaths per week, as well as uncertainty because these are estimated based on a statistical model of historical data.[11] The data show that the weekly reported deaths in South Africa are consistently within the 95 per cent confidence interval of expected deaths, hence there is no evidence during the period of 1 January to 14 April 2020 of excess mortality. Note that the reporting of deaths has been adjusted for delayed registration.

11 The Microsoft Excel 'FORECAST' function uses exponential smoothing algorithm for such forecasts.

**Figure 2: Weekly deaths, all causes, South Africa (1 January to 14 April 2020)**




*Number for the last week has been adjusted for delayed registrations.*

Source: Bradshaw, D et al, 2020, Report on weekly deaths in South Africa, 1 January-14 April 2020. https://www.samrc.ac.za/sites/default/files/files/2020-04-23/WeeklyDeaths_14April2020.pdf

While measuring excess deaths is easier in countries where the CRVS system has captured most (or all) deaths in a timely and accurate manner, it is still possible to produce reliable estimates even with incomplete registration.

## Measuring excess mortality using CRVS data

The gold standard for measurement of mortality in a population is a timely and complete civil registration and vital statistics (CRVS) system. The advantage of a CRVS system to measure excess mortality is that, when complete, it will capture all deaths in a population, irrespective of whether the deaths occurred in hospital or in the community. However, death registration in many countries is incomplete, which presents challenges when measuring excess mortality. An estimated 35 per cent of global deaths are not registered and 70 per cent of the world's deaths occur in countries where death registration is less than 95 per cent complete.[12]

This document provides operational guidance for data analysts to measure excess mortality as a result of COVID-19, particularly focusing on CRVS systems with incomplete death registration. It provides guidance to measure excess mortality for three scenarios of death registration completeness:

1. **High completeness:** greater than 90 per cent complete. This will likely be higher for adults and the elderly, ages where almost all excess mortality occurs.
2. **Medium completeness:** 50-90 per cent complete
3. **Low completeness:** less than 50 per cent complete

12 We define completeness as being the percentage of actual deaths in a population that are registered. This definition also applies to death notification or death reporting systems. Throughout this document we refer to death registration, but it is also applicable to death notification and death reporting.

The measurement of excess mortality during the COVID-19 pandemic relies upon the following data:

1. Deaths *expected* to have occurred in the absence of the pandemic. These are calculated based on historical data.

AND EITHER

2a. Deaths *reported* to have occurred (i.e. for death registration systems greater than 90 per cent complete)

OR

2b. Deaths *estimated* to have occurred (our best estimate of the actual number of deaths that occurred, adjusting for incomplete death registration, i.e. for death registration systems less than 90 per cent complete).

The calculations to measure excess mortality are presented in the following section for each of the three levels of death registration completeness.

## Measuring excess deaths from a complete (greater than 90 per cent) death registration system

### Calculating *expected* deaths

The calculation of expected deaths should be based on recent historical data; where possible this should be for the last five years. The following steps are then applied:

**Step 1**

Before using these data to estimate expected deaths, it is important to check each year of data for any mortality "shocks", such as other epidemics or natural disasters, which might not represent long-term mortality trends. If these exist, they should be removed from the data.

**Step 2**

Use the trend line of the deaths in the historical data to estimate expected deaths in the period of interest. You can use the FORECAST function in Excel, or your own statistical time series model.[13] Note that the use of average number of deaths in the last five years may bias the number of expected deaths because it does not account for trend in these indicators. An alternative is to use crude death rate (CDR, deaths divided by population multiplied by 1000) as the basis for calculating expected deaths, if the rate of change in population size has varied in the last eight years.

*Calculating expected deaths, annual estimates*

The following is an example of estimating expected deaths where there is complete death registration (**Table 1**). In this example the Microsoft Excel "FORECAST" function was applied to the yearly deaths from 2015-2019 to estimate annual deaths in 2020. 26 643 deaths were estimated for 2020. Because of an increase in registered deaths each year in the historical data, due to the population also increasing, use of an average number of deaths over the past five years will significantly underestimate expected deaths compared with using a model of the trend, hence why the use of averages should be avoided.

13 Some more advanced statistical models to estimate expected deaths are those by Goldstein et al. 2012 and Noufaily et al 2013. Goldstein E, Viboud C, Charu V, Lipsitch M. *Improving the estimation of influenza-related mortality over a seasonal baseline*. Epidemiology. 2012;23(6):829838. doi:10.1097/EDE.0b013e31826c2dda, Noufaily A, Enki DG, Farrington P, Garthwaite P, Andrews N, Charlett A. *An improved algorithm for outbreak detection in multiple surveillance systems*. Statistics in Medicine. 2013;32(7):1206–1222. 10.1002/sim.5595

**Table 1: Example of estimating expected deaths, high completeness of death registration**

| Year | Registered deaths | Population |
|---|---|---|
| **2015** | 23,026 | 4,229,266 |
| **2016** | 23,688 | 4,259,155 |
| **2017** | 24,238 | 4,267,253 |
| **2018** | 25,002 | 4,311,103 |
| **2019** | 25,986 | 4,389,527 |
| | **Expected deaths** | |
| **2020 (5-year average)** | 24,729 | |
| **2020 (projected)** | 26,643 | 4,465,111 |

*Calculating expected deaths, periodic estimates*

Estimation of expected deaths can be conducted based on annual deaths, as above, but also weekly or monthly deaths (for small populations, however, there can be substantial random variation in weekly or monthly deaths, so use of annual deaths is preferable). Expected deaths for a period of time within a calendar year can be calculated based on the annual estimates. This is straightforward once the period of interest is determined. Using the data from **Table 1**:

- From historical data, calculate the proportion of registered deaths that occur in the period of interest, and multiply this proportion by the expected deaths for 2020.

  For example, if the period of interest is March to April 2020, and your historical data show that 17 per cent of deaths occur in March and April, then:

  = 17% x 26 643

  = 4529 expected deaths in March to April 2020

## Calculating *excess* deaths

The calculation of excess deaths where death registration is complete is (using the data and subsequent calculations from **Table 1**):

- Excess deaths = registered (observed) deaths – expected deaths

  For example, if there were 5921 observed deaths in March to April 2020:

  **Excess deaths** = 5921 – 4529

  **= 1392** or **31 per cent higher than expected**

Before making this calculation, however, it is worthwhile assessing your historical data for the timeliness of registration. If you use very recent death registration data, some deaths within the period may not yet be registered, which will lead to an underestimation of the number of registered deaths. It should also be noted that there may be delays in registration if registration services have been adversely affected by the pandemic. You should only use registered deaths in this calculation if all (or almost all) the deaths that occurred in the period of interest would be expected to have already been registered.

*Calculating uncertainty in excess deaths*

Uncertainty in excess deaths can also be calculated. A widely used calculation of the 95 per cent confidence interval of death numbers is:

$Deaths \pm (1.96 \ \sqrt{Deaths})$

For 5921 observed deaths:

$5921 \pm (1.96 * \sqrt{5921})$

$= 5770 \ to \ 6072$

The 95 per cent confidence interval of observed deaths is 5770 to 6072. After subtracting expected deaths, the **95 per cent confidence interval of excess deaths is 1241 to 1543, or 27 per cent to 34 per cent**.

## Measuring excess deaths in countries with incomplete CRVS data

**Key considerations**

The use of incomplete death registration data to estimate excess deaths presents a number of challenges. Before calculating excess deaths, there are some considerations which will affect accuracy of the estimation of excess deaths. The methods presented in this document seek to reduce bias due to some of these issues, however. others may only be able to be assessed based on local knowledge:

- How complete are the CRVS data? Use of incomplete death registration data to calculate excess deaths may under-estimate the true number of excess deaths (the following section provides guidance for calculating the completeness of death registration).
- Is the completeness of CRVS data during the COVID-19 pandemic different from the normal level of completeness? Registration activities may be adversely affected because of the pandemic, for example, because of staff redeployed away from registration services because of the pandemic or social distancing preventing many people from registering deaths that they may otherwise. Additionally, there may have been investments in the CRVS system in recent years to increase registration, which may act to support increases in registration completeness.
- Are the excess deaths due to the COVID-19 pandemic more or less likely to be captured by the death registration system? This relates to the previous point, but specifically focuses on whether the additional deaths due to the pandemic have characteristics that mean they are more or less likely to be registered. For example, if the excess deaths are disproportionately occurring in hospitals, and hospital deaths are more likely to be registered than community deaths, then it is important to account for this. The methods in the following sections address this issue.

Some more generic considerations about the quality of deaths registration include:

- Do death data refer to date of occurrence of death, and not date of registration? Date of occurrence should always be used.
- Is late registration an issue (see earlier discussion)?
- Is there a consistent definition of residence for decedents for both deaths and population? This is especially important for mortality in large cities, where many non-residents would die in hospitals. Place of usual residence should be the definition used in both death and population data.
- How accurate is reporting of age at death? This should be calculated from date of death and date of birth data, and not be based on reporting of age at death (which commonly causes an over-reporting of deaths at ages ending in 0 and 5).

**Measuring completeness of registration**

*Empirical completeness method*

The empirical completeness method measures completeness of death registration (or death notification/reporting) using the following data inputs, which are readily available at the national and subnational level:

- Registered crude death rate: This is the number of deaths divided by the population multiplied by 1000
- Under-five mortality rate (5q0): This is the best estimate of the true 5q0 and represents the level of mortality
- Percentage of the population aged 65 and over: This represents the population age structure
- Completeness of under-five death registration: This is the 5q0 calculated from the registration data, divided by the true 5q0.

Below is an example of the empirical completeness method for a hypothetical country in 2014. The input data are shown in **Table 2.**

**Table 2: Input data to estimate completeness of registration**

| Registered CDR | % population 65+ | 5q0 | Under-5 completeness | Year |
|---|---|---|---|---|
| 3.077 | 6.60% | 0.0181 | 45% | 2014 |

Below is the equation used in the empirical completeness method (Model 1) to calculate completeness for both sexes based on the input data. Bolded figures are the model coefficients, which are the same for all populations.

$\text{logit}\ (C_{jk}^{All}) = (\mathbf{-0.0177} * 3.077^2) + (\mathbf{0.6375} * 3.077) + (\mathbf{-13.8914} * 0.0660) + (\mathbf{-1.1136} * \ln(0.0181)) + (\mathbf{2.2063} * 0.45) + (\mathbf{-0.0174} * 2014) + \mathbf{29.3677} = 0.6617$

$$= \frac{e^{0.6617}}{e^{0.6617}+1} = 66.0\%$$

That is, completeness in 2014 is estimated to be 66 per cent.

A significant strength of this method is that it can reliably estimate completeness for subnational populations. It is however not recommended for use in countries where there is significant HIV/AIDS mortality, because it will likely overestimate completeness. The completeness method is automatically calculated in the ANACONDA software tool which assess the quality of mortality and cause of death data.[14]

*Simpler way of measuring completeness*

A more straightforward method of estimating death registration completeness to obtain an estimate of total deaths from a reliable source and use this equation:

*Completeness = registered deaths ÷ estimated total deaths × 100*

Reliable sources of estimated total deaths are produced by the Global Burden of Disease (GBD) study and the United Nations World Population Prospects (UN WPP), which both estimate total deaths for each country and, for the GBD, some subnational areas of large countries (e.g. Brazil). Another source is the country's national statistical office estimates, which should produce estimates at the subnational level. In addition, the estimated CDR can also be used to estimate completeness.

It may not be correct to assume, however, that the national CDR is the same as for the subnational level for which you wish to calculate completeness.

14 Full details of the empirical completeness method, including an alternative model that does not use the under-five death registration completeness variable, as well as the models for males and females, can be found here: Adair, T., Lopez, A.D., 2018, Estimating the completeness of death registration: An empirical method, PLoS ONE, 13(5): e0197047.

### Measuring excess deaths from a system with medium registration completeness (50 to 90 per cent)

*Calculating expected deaths*

Consistent with countries with high registration completeness, expected deaths should be calculated based on data from the last five years. Some additional steps also need to be undertaken:

- Calculate completeness of registration for each year
- If you are using empirical completeness method, estimated deaths for each year need to be calculated: *Estimated deaths = registered deaths ÷ completeness (as a fraction)*
- If you have estimated total deaths for each year from a reliable source, use that in your historical data. Completeness will still need to be calculated (i.e. registered deaths divided by estimated total deaths) to adjust deaths at a later stage. Remember that constant completeness over time cannot always be assumed (as discussed above).

Once the estimated deaths for each year from historical data have been calculated, the same method to estimate deaths in the year and period of interest as for countries with high registration completeness (presented in previous section) should be used.

**Table 3** presents an example of estimating excess deaths where completeness of registration is 70 per cent. In this example, completeness has remained steady at 70 per cent during the 2015-2019 period. In 2020, 18 141 deaths are expected to occur.

**Table 3: Example of estimating expected deaths, medium completeness of death registration**

| Year | Registered deaths (1) | Completeness (2) | Estimated total deaths (1 ÷ 2) | Population |
|---|---|---|---|---|
| **2015** | 11,513 | 70% | 16,447 | 2,349,592 |
| **2016** | 11,744 | 70% | 16,777 | 2,382,486 |
| **2017** | 11,919 | 70% | 17,027 | 2,415,841 |
| **2018** | 12,201 | 70% | 17,430 | 2,449,663 |
| **2019** | 12,493 | 70% | 17,847 | 2,483,958 |
| | | | **Expected deaths** | |
| **2020 (projected)** | | | 18,141 | 2,518,734 |

Calculating expected deaths for the time period of interest is the same as in the example of high registration completeness countries, presented in the previous section of this document. If 17 per cent of deaths each year occur in March and April, then:

Expected deaths = 17% × 18 141

**= 3084 expected deaths in March to April 2020**

*Calculating excess deaths*

Before calculating the number of deaths estimated to have occurred during the pandemic for countries with incomplete death registration, the key considerations mentioned at the start of this section should again be kept in mind.

**Table 4** presents an example of estimating the number of deaths to have occurred during March to April 2020. Because completeness was steady at 70 per cent during 2015-2019, this is assumed to be the level of completeness in 2020. However, this figure may be adjusted if there is evidence that registration completeness may be higher or lower during the pandemic for the reasons discussed earlier. In the following example, 2768 deaths were registered in March to April 2020.

**Table 4: Example 1 of estimating deaths to have occurred during March-April 2020, medium completeness of death registration**

| | Registered deaths (1) | Completeness (2) | Estimated total deaths (1 ÷ 2) | Expected deaths (from above) |
|---|---|---|---|---|
| **Total** | 2,768 | 70% | 3,954 | 3,084 |

Using the data from **Table 4:**

Excess deaths = 3954 – 3084

**= 870 excess deaths, or 28 per cent higher than expected**

The accuracy of excess deaths can be improved if there are informed estimates of completeness for sub-groups of the population. This is important if the excess deaths in the pandemic are more or less likely to be registered in normal deaths; by calculating excess deaths using completeness of sub-groups, this will reduce inaccuracy from this issue. When estimating excess deaths nationally, it is particularly useful to estimate excess deaths for each subnational area, because both completeness and the extent of excess mortality will differ by subnational area.

Another good example is that if excess deaths disproportionately occur in hospitals compared with the community, then you can reduce bias from this by separately estimating completeness for deaths that occur in hospitals compared with deaths that occur in the community. Measurement of the percentage of hospital deaths that are registered is quite challenging, so qualitative information can be valuable. It is important to not always assume that all hospital deaths are registered, even if there are assurances that this is the case. It is also necessary to ensure that hospital deaths that registered are only those of usual residents of the location for which you are measuring excess deaths.

Building on the example in Table 4, in **Table 5** we estimate that completeness of registration of hospital deaths is 90 per cent, and 57 per cent for community deaths. This results in 3880 deaths estimated to have occurred during March to April 2020, less than the example in Table 4 (because the excess deaths are disproportionately in hospitals, where registration completeness is higher).

**Table 5: Example 2 of estimating deaths to have occurred during March-April 2020, medium completeness of death registration**

| | Registered deaths (1) | Completeness (2) | Estimated total deaths (1 ÷ 2) | Expected deaths (from above) |
|---|---|---|---|---|
| **Hospital** | 1,517 | 90% | 1,686 | |
| **Community** | 1,251 | 57% | 2,195 | |
| **Total** | 2,768 | | 3,880 | 3,084 |

Using the data from **Table 5:**

Excess deaths = 3880 – 3084

**= 796, or 26 per cent higher than expected**

### Measuring excess deaths from a system with low registration completeness (less than 50 per cent)

*Calculating expected deaths*

In populations with low death registration completeness, it is not recommended to estimate total deaths from the estimate of completeness using the empirical completeness method. This is because uncertainty in the estimate of completeness is amplified when estimating total deaths, due to the inverse of completeness, which is multiplied by registered deaths to calculate estimated total deaths, being much higher (e.g. three when completeness is 33 per cent). Therefore, it is instead recommended in your historical data to use estimated total deaths from a reliable data source, such as the GBD, UN WPP or national statistics office. Completeness should still be calculated from the estimated total deaths (registered deaths divided by estimated total deaths).

The process for estimating expected deaths is otherwise the same as for countries with medium completeness.

*Calculating excess deaths*

**Table 6** presents an example of estimating deaths to have occurred during March to April 2020 where completeness of death registration is 35 per cent. This assumes that there were 7250 expected deaths estimated for 2020 (based on historical data), which results in 1233 deaths in March to April (multiplying 7250 by 17 per cent as done earlier).

Where there are 561 registered deaths, the estimated total deaths during March to April 2020 is 1603.

**Table 6: Example of estimating deaths to have occurred during March-April 2020, low completeness of death registration**

| | Registered deaths (1) | Completeness (2) | Estimated total deaths (1 ÷ 2) | Expected deaths (from above) |
|---|---|---|---|---|
| **Total** | 561 | 35% | 1,603 | 1,233 |

Using the data from **Table 6:**

Excess deaths = 1603 – 1233

**= 380, or 30 per cent higher than expected**

## Understanding the characteristics of deaths during the pandemic and excess deaths

It is good practice to compare the characteristics of registered deaths during the COVID-19 pandemic with your historical data. This may tell you much about the excess mortality occurring during the pandemic, especially if registration completeness is high. Characteristics of the deaths and decedents can include causes of death, age group of death, and place of death, among others. To do this, you can either:

1. Compare the percentage of all registered deaths during the pandemic and the historical data that are due to each characteristic, or;
2. a) Calculate the number of additional registered deaths in the pandemic (which is excess deaths where registration is complete) compared with the average number for the same time period in the historical data.

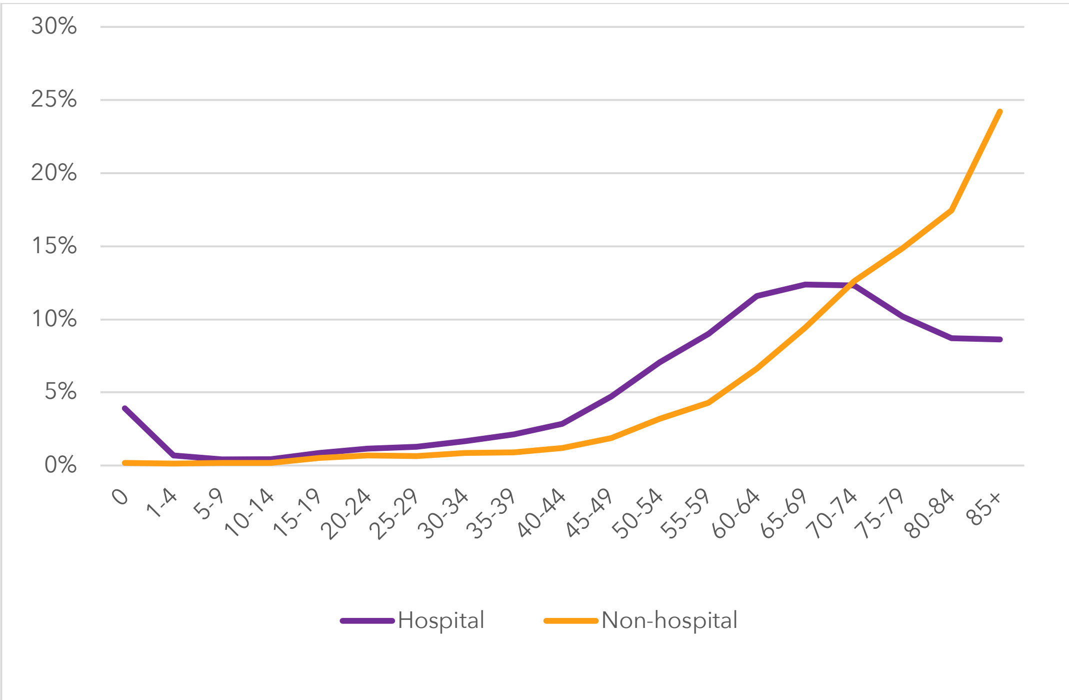
   b) For each characteristic, calculate the difference between registered deaths in the pandemic and average registered deaths in the same time period in the historical data.

   c) For each characteristic, calculate b) divided by a). This will provide an estimate of the percentage of additional registered deaths in each characteristic, whether it be cause of death, age group, or place of death.

The impact of the pandemic on the cause of death distribution may indicate whether there are excess deaths are due to causes directly linked to COVID-19, or potentially other causes that are a more indirect impact of the pandemic, for example, reductions in access to health services or economic disruption. In point two above, the percentage of excess deaths that have a cause of COVID-19 is important to assess. For example, if there were 350 deaths during March to April 2020 with COVID-19 as the cause, and 870 excess deaths (example from earlier), then deaths with COVID-19 as the cause would comprise 40 per cent of the estimated excess deaths. You will need to ask whether this is a reasonable estimate, keeping in mind that this indicator can vary greatly between populations, especially because of differences in levels of testing of COVID-19 and certification practices.

Using the calculation in point one above, it may also be that the impact of COVID-19 has increased the percentage of deaths at older ages and in hospitals. There could also be a drop-off in deaths at younger ages if there has been an adverse impact on registration services. For example, **Figure 3** compares typical age distributions of hospital and non-hospital deaths. In many countries, hospital deaths due to COVD-19 will be older than other hospital deaths which commonly have a disproportionately high number of neonatal and child deaths. During the COVID-19 pandemic, the age distribution of hospital deaths may be more similar to that normally found for non-hospital deaths.

**Figure 3: Common age distribution of hospital and non-hospital deaths (% of deaths at all ages)**




CRVS best-practice and advocacy

## Conclusion

Reliably measuring excess deaths can provide a comprehensive and timely estimate of the true overall impact of the COVID-19 pandemic on a population. While measurement is easier when a CRVS system has captured most (or all) deaths in a timely and accurate manner, it is still possible to estimate excess deaths even in countries with incomplete registration. Such methods require the adjustment of incomplete mortality data, as instructed in this guidance document, however, calculations under such circumstances will inevitably be far less reliable than where complete and timely death registration data are available. When interpreting calculations of excess deaths, it is also very important to routinely and thoroughly interrogate aspects of the data, such as age distribution of deaths, since most COVID-19 deaths should occur at the oldest ages.

For countries with incomplete CRVS systems, a key priority will be to implement timely and cost-effective death notification systems, which can, at least for a representative sample of the population, capture all deaths due to COVID-19 and not just those occurring in hospitals. Advances in information technology and communications platforms, including the vast and in many countries virtually universal prevalence of mobile phone technology, can readily be exploited by national statistics offices to dramatically improve death notification, especially for deaths that occur at home. Establishing such systems will allow countries to routinely monitor COVID-19 mortality along with other existing and emerging public health priorities with much greater confidence that is currently the case.

The program partners on this initiative include: The University of Melbourne, Australia; CDC Foundation, USA; Vital Strategies, USA; Johns Hopkins Bloomberg School of Public Health, USA; World Health Organization, Switzerland.

Civil Registration and Vital Statistics partners:

## For more information contact:


CRVS-info@unimelb.edu.au

crvsgateway.info



CRICOS Provider Code: 00116K

Version: 0620-01