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Quality-Adjusted Life-Years Lost Due to COVID-19 Mortality: Methods and Application for The Netherlands

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ABSTRACT

Objectives: The COVID-19 pandemic has increased mortality worldwide considerably in 2020. Nevertheless, it is unknown how the increase in mortality translates into a loss in quality-adjusted life-years (QALYs), which is a function of age and the health condition of the deceased patient at time of death. We estimate the QALYs lost in The Netherlands as a result of deaths because of COVID-19 in 2020.

Methods: As a starting point, we use estimates of underlying diseases and the number of COVID-19 deaths in nursing homes as a proxy for underlying health status. In a next step, these are combined with estimates of excess mortality rates and quality of life for different groups to calculate QALYs lost. We compare the results with an alternative scenario, in which COVID-19 deaths occurred randomly across the population regardless of underlying conditions. For this alternative scenario, we use population mortality and average quality of life by age and sex.

Results: Accounting for underlying health status, we estimate that QALYs lost because of COVID-19 mortality are on average 3.9 per death for men and 3.5 for women. This is approximately 3.5 QALYs less than when not taking selective mortality into account. Given 16,308 excess deaths, this translates into 61,032 QALYs lost because of COVID-19.

Conclusions: We conclude that QALYs lost because of COVID-19 mortality are still substantial, even if mortality is strongly concentrated in people with poor health.

Keywords: COVID-19, disease burden, quality-adjusted life-years, years of life lost.

Introduction

COVID-19 has a global impact on mortality but little is known about the number of life-years and quality-adjusted life-years (QALYs) lost. Understanding health lost because of COVID-19 mortality is important to policy makers because it can help determine the impact of measures taken to mitigate the effects of the pandemic. Although COVID-19 also has an effect on the health of individuals who survive, some of whom might be having long COVID-19 for a long period of time, the health lost among those dying of COVID-19 forms a major part of the total health burden. One reason that little is known about the health effect of COVID-19 mortality is the uncertainty about the role of risk factors and comorbidity. The number of QALYs lost because of COVID-19 mortality depends on the health of the people who die of COVID-19. People in poor health have a lower remaining life expectancy on average than healthy people. Hence, if people in poor health are at an increased risk of dying of COVID-19, the number of QALYs lost is smaller than when deaths occur randomly among the general population. Previous work by Briggs et al stressed the mechanism of underlying health status affecting QALYs lost, but with little empirical evidence to support calculations. A recent study for the United States, which takes the broader health effects beyond mortality into account, finds that almost 80% of the total QALY loss per COVID-19 infection is because of death. Nevertheless, their estimates of QALYs lost because of death are based on age-specific averages and thus potentially an overestimation.

The age pattern of the COVID-19 mortality shows that there is a likely relation with underlying health. Spiegelhalter analyzed COVID-19 mortality in England and showed that the age pattern of the COVID-19 mortality is almost proportional to that of the normal mortality, which means that COVID-19 mortality increases exponentially with age. A relatively large number of studies have now been conducted into the characteristics of patients with COVID-19 (eg, Wynants et al). We focus on the relationship between underlying conditions and death. What has consistently emerged is that men, the older population, and people with overweight, diabetes, lung disease, or chronic heart failure have a higher chance of dying of COVID-19 (eg, Bhaskaran et al and Clift et al). Nevertheless, the sample of deceased patients is quite low in most studies. This is especially the case in Dutch studies.
In this article, we combine several data sources to have an empirically based estimate of QALYs lost because of COVID-19 mortality. We use estimates of underlying disease and the number of COVID-19 deaths in nursing homes as a proxy for underlying health status. In a next step, these are combined with estimates of excess mortality rates and quality of life (QOL) conditional on health status to calculate QALYs lost. The methods we use can serve as a template for such calculations in other countries.

Methods

Deaths Due to COVID-19 and Underlying Health Status

To establish the number of COVID-19 deaths by age in 2020, we use estimates of excess mortality provided by Statistics Netherlands. These were calculated by taking the difference in the number of deaths per week in 2020 compared with the (pre-COVID-19) expected number of deaths, where the expectation is based on the population forecast using observed mortality in the years 2015 to 2019. We consider the weeks in which there was a COVID-19 wave (weeks 10-20 and weeks 39-53). The excess mortality in these weeks amounts to 16,308 deaths. Excess mortality over the whole of 2020 was lower (14,481), because some individuals in a poor health state, who would have otherwise died at a later moment in 2020, died during the first COVID-19 wave. Because this is exactly the mechanism that we take into account by looking at life-years lost by previous health, we use excess mortality in the COVID-19 waves only. The alternative approach to identify deaths because of COVID-19 would be to look at registered causes of death. At the time of research, these data were only available up to week 44 and over this period were very similar to our estimates.

To attribute COVID-19 deaths to individual ages, we start with excess mortality split into 3 large age groups (0-65, 65-80, 80+ years). We then assign deaths within these groups to smaller 5-year groups based on the age patterns of COVID-19 deaths observed for a smaller part of the population registered by the National Institute for Public Health and the Environment (RIVM). Finally, we spline these to obtain estimates by individual age. Appendix A in Supplemental Materials found at https://doi.org/10.1016/j.jval.2021.12.008 shows the age patterns in the source data and the resulting (splined) age profile.

To capture preexisting differences in health and survival between individuals who died of COVID-19 and the general population, we use 2 approaches. First, for individuals who died of COVID-19 in the hospital or at home, we use data on comorbidities. The RIVM publishes the underlying diseases of a part of the officially registered Dutch COVID-19 deaths under the age of 70 years. Among the 932 included COVID-19 deaths, 35.7% had chronic heart failure, 22.6% diabetes, and 21.1% chronic obstructive pulmonary disease (COPD). These numbers are comparable with the much larger study in England. Data on the comorbidities of individuals > 70 years of age who die at home or in the hospital are not available. Therefore, we used the same prevalence rates as for those < 70 years of age. Given that comorbidities tend to increase with age, this means that for the oldest groups we are likely underestimating comorbidities.

Second, many of the people in The Netherlands who died of COVID-19 lived in the nursing home. Although only approximately 4.7% of all Dutch individuals > 65 years of age live in a nursing home, approximately 50% of male and 70% of female COVID-19 deaths occurred in this setting. Nursing home inhabitants generally have severe disabilities, have multiple chronic conditions, and use a relatively large amount of medical care and medication in the year before their admission. Just looking at comorbidities for this population does not sufficiently capture their poor health and low survival compared with the general population. Therefore, we use living in a nursing home as a separate “condition” for which we obtain data on conditional survival and health.

From Deaths to QALYs Lost

QALYs lost because of COVID-19 depend crucially on the distribution of COVID-19 deaths across ages and different health groups. We use 5 different health groups: individuals with COPD, diabetes, chronic heart failure, living in a nursing home, and the remaining population. For each of these groups, we first estimate remaining quality-adjusted life expectancy (QALE) by age and sex:

\[
QALE_{a,g,h} = \sum_{b=0}^{99} \left( q_{a,g,h} \prod_{b}^{99} s_{b,g,h} \right).
\]

with \( s_{a,g,h} \) the annual survival probability and \( q_{a,g,h} \) average QOL for health group \( h \), age \( a \), and sex \( g \). Then we multiply these with the number of COVID-19 deaths, \( d_{a,g,h} \), by age and sex across health group and sum up to arrive at the total number of QALYs lost (QYLL):

\[
QYLL = \sum_{h=1}^{5} \sum_{a=1}^{99} d_{a,g,h} QALE_{a,g,h}.
\]

Excess mortality rates for people with diabetes, COPD, and heart failure were taken from the RIVM Chronic Disease Model. For the nursing home population, mortality rates are based on Wouterse et al., who estimated a mixed effects proportional parametric survival model for mortality among newly admitted clients to Dutch nursing homes over the period 2010 to 2013. COVID-19 deaths that occurred in a nursing home are reported split by sex and then splined. COVID-19 deaths outside the nursing home are attributed to the other health groups based on the previously introduced fractions reported by the RIVM. Mortality rates for the rest of the population were calculated from the mortality rates of the total population minus age-specific prevalence of the disease groups times the excess mortality rates of these groups.

We searched the literature for review articles reporting on utilities for diabetes, heart failure, and COPD. From these reviews, we identified the estimates that we used in our analyses. QOL in the remaining life-years for people with diabetes was based on the 3-level version of EQ-5D (EQ-5D-3L) average QOL of diabetics without complications. For COPD, QOL was assumed to equal the average QOL of people with COPD in the so-called Gold III severity class. For heart failure we assumed the EQ-5D-3L average QOL of patients in the New York Heart Association III class.

These 3 QOL values were all derived from the EQ-5D instrument using the UK value set. We transformed UK values to Dutch values with a linear model that was estimated by regressing the Dutch utility values on the UK ones using a data set with utility values for all 243 EQ-5D-3L health states. The resulting values are 0.80 for diabetes, 0.73 for COPD Gold, and 0.64 for heart failure. QOL in nursing homes was set at 0.49, which represents EQ-5D-3L based average QOL in a Dutch nursing home sample using the Dutch value set. QOL for those who died of COVID-19 of the most healthy group was based on average QOL estimates by age and sex for the community-dwelling population in The Netherlands corrected for QOL losses because of diabetes, COPD, and heart failure.
We compare estimates of QALYs lost as described earlier with a naive estimate in which we assume that COVID-19 deaths occur randomly within the population conditional on age and sex, regardless of previous health. If this is the case, the QALYs lost depends solely on the age and sex distribution of COVID-19 deaths. For this naive estimate, we used population mortality rates and average QOL of the community-dwelling population in The Netherlands.\(^{27}\)

An overview of the data sources used is provided in Appendix B in Supplemental Materials found at https://doi.org/10.1016/j.jval.2021.12.008.

**Results**

Table 1 shows the total and average number of (quality-adjusted) years of life lost because of COVID-19 mortality in 2020, according to the adjusted, health-specific estimate and to the naive estimate. According to the adjusted estimate, 51,668 life-years were lost for men and 38,071 for women. This corresponds to an average of approximately 5.5 years of life lost per COVID-19 death. When we correct for QOL, we get an average of 3.9 QALYs lost per death for men and 3.5 for women.

Not taking into account that COVID-19 deaths are concentrated among individuals with previous health problems leads to considerably higher estimates of both life-years and QALYs lost. For men, the naive estimates are a total of 81,947 years of life lost, corresponding to an average of 8.8 years of life lost and 7.4 QALYS. For women, the total number of years of life lost is 47,076, the average life-years lost is 8.7, and the average QALYs lost is 6.9.

Figure 1 shows total QALYs lost by age according to both estimates. Total QALYs lost is a function of the number of COVID-19 deaths (increasing in age) and the number of remaining QALYs (decreasing in age). For men, the highest number of QALYS lost is at age 78 years: 1,379 based on the adjusted estimate. For women, the highest number of QALYS occurs at a slightly higher age, at 80 years, with 831 QALYS lost. The naive estimates (naturally) always higher than the adjusted health-specific estimates, with the largest difference occurring between ages 75 to 85 years. The small discontinuity around age 65 years in the adjusted estimate is due to the fact that we start accounting for nursing home use from that age.

**Discussion**

This article presents estimates of the QALYS lost because of deaths from COVID-19 in 2020 in The Netherlands. The results suggest that, even when mortality is concentrated in people with poorer health, the mean number of QALYs lost per COVID-19 death...
can be substantial. Taking into account the health status of the people who died of COVID-19, we arrive at an estimate of approximately 3.9 QALYs lost per male COVID-19 death and 3.5 QALY loss per female COVID-19 death. The results show that it is vital to take health status of patients with COVID-19 into account when estimating QALYs lost. An alternative approach, assuming that COVID-19 deaths occur randomly within age groups, arrives at estimates of 7.4 and 6.9 QALYs lost.

Previous studies that tried to quantify the health burden of COVID-19 ignored previous health status. An important reason for this might be that individual data on the previous health state of patients with COVID-19 are still scarce in many countries. Briggs et al.\(^1\) apply a similar framework as ours for a number of countries. Because they lack empirical data to estimate differences in mortality and QOL between patients with COVID-19 and the general population, they rely on an informed guess. We have chosen a middle ground, combining available data on underlying diseases of individuals who die of COVID-19 with data on excess mortality for the most common disease groups from already existing sources. As comparable data will likely become available in many countries, our methods can serve as a template for calculations of the disease burden of COVID-19.

A previous study by the RIVM, in which estimates were presented of the number of years of life lost as a result of the first COVID-19 wave, was based on general life expectancy and concluded that approximately 9.5 years of life were lost per COVID-19 death. This is comparable with our naïve estimate of approximately 9 years. Taking into account the health status of the COVID-19 deaths, we arrive at estimates that are approximately one-third lower (5.5 years). This correction for underlying health is relevant and matches popular opinion that COVID-19 affects those with underlying conditions. Nevertheless, in public discourse, this has sometimes been exaggerated to the extent that very little, if any, life would be lost from premature death because of COVID-19. Our results strongly contradict this and show that even when mortality is selective, quite a few years of life are still lost per COVID-19 death. With a total number of life-years lost as a result of the COVID-19 mortality in 2020 of approximately 90,000, COVID-19 is at the top of the diseases with the highest health burden together with lung cancer, coronary heart diseases, and dementia.\(^2\)

To arrive at the estimates of the number of QALYs lost, we had to make some important assumptions. These concern both the number of deaths from COVID-19 and underlying health status and the remaining quality-adjusted life expectancy of the different groups. First, we used the excess mortality in the COVID-19 period in 2020 as a definition for COVID-19 mortality. For the first wave, the number of COVID-19 deaths according to the over-mortality definition is in line the numbers based on cause of death, which gives confidence in this definition.

Second, we had to make assumptions about the exact age patterns of the COVID-19 deaths, because detailed data on this are still lacking. Third, with regard to the remaining life expectancy for patients with diabetes, COPD, and congestive heart failure, we used estimates from the RIVM Chronic Diseases Model.\(^1\) The starting point is the difference in mortality between people with and without a particular disease, which is not the same as the mortality from that disease.\(^3\) For example, observed higher mortality among patients with diabetes is partly caused by the fact that they are more likely to be obese and have a higher risk of cardiovascular disease. Although the estimates of remaining life expectancy take into account comorbidity, they are still group averages. If within each health group the relatively unhealthy, disabled, and frail people have died, our estimates of the number of years of life lost, even in the most select scenario, could still be an overestimation. Similarly, there likely is within-group heterogeneity in QOL. For QALYs of the disease groups, we had to rely on non-age-specific estimates. Obtaining age-specific estimates per disease group would be a first step in capturing an important part of this heterogeneity. To give some indication of the sensitivity of our estimates to the utility values used for each disease, Appendix C in Supplemental Materials found at https://doi.org/10.1016/j.jval.2021.12.008 provides alternative values of the total loss in QALYs based on the lower and upper bound of the underlying estimates of these utilities and on the utility values of more severe disease categories of COPD, chronic heart failure, and diabetes: Depending on these alternative assumptions, our estimates of QALYs lost per COVID-19 death lie between 3.6 and 4.2 for men and 3.3 and 3.7 for women.

The estimates in this article should be seen as an initial effort to empirically quantify the effect of COVID-19 mortality in 2020 on public health. As more detailed data will become available in the coming years, more precise estimates of the number of healthy life-years lost because of the COVID-19 pandemic will become possible (eg, see Clift et al.\(^4\) for the potential of detailed population-based studies). Combining microdata on previous health, socioeconomic status, and other relevant characteristics will eventually make it possible to quantify life-years lost at the individual level, not only for those who died of COVID-19 but also for those who survived and might be experiencing a long-term impact on their health. Nevertheless, policy makers cannot wait for this information because they have to make policy decisions now, for which the health loss because of COVID-19 mortality is an important input.

**Supplemental Materials**

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.jval.2021.12.008.

**Article and Author Information**

Accepted for Publication: December 12, 2021

Published Online: February 2, 2022
doi: https://doi.org/10.1016/j.jval.2021.12.008

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Obtaining funding: Wouterse, van Baal
Supervision: Wouterse, van Baal

Conflict of Interest Disclosures: All authors reported receiving funding from the Network for Studies on Pensions, Aging and Retirement (NETSPAR). Dr Pieter van Baal is an editor for Value in Health and had no role in the peer review process of this article. No other disclosures were reported.

Funding/Support: This work was funded by NETSPAR (www.netspar.nl) through a NETSPAR Topicality Grant.

Role of the Funders/Sponsors: The funder had no role in the design and conduct of the study; collection, management, analysis, and interpretation.
of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Acknowledgment: The authors thank Matthijs Versteegh for his critical input on draft versions of this article.

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