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Estimating the health impact of delayed elective care during the COVID -19 pandemic in the Netherlands

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ABSTRACT

Background: The COVID-19 pandemic had a major impact on the continuity of healthcare provision. Appointments, treatments and surgeries for non-COVID patients were often delayed, with associated health losses for patients involved.
Objective: To develop a method to quantify the health impact of delayed elective care for non-COVID patients.
Methods: A model was developed that estimated the backlog of surgical procedures in 2020 and 2021 using hospital registry data. Quality-adjusted life years (QALYs) were obtained from the literature to estimate the non-generated QALYs related to the backlog. In sensitivity analyses QALY values were varied by type of patient prioritization. Scenario analyses for future increased surgical capacity were performed.
Results: In 2020 and 2021 an estimated total of 305,374 elective surgeries were delayed. These delays corresponded with 319,483 non-generated QALYs. In sensitivity analyses where QALYs varied by type of patient prioritization, non-generated QALYs amounted to 150,973 and 488,195 QALYs respectively. In scenario analyses for future increased surgical capacity in 2022–2026, the non-generated QALYs decreased to 311,220 (2% future capacity increase per year) and 300,710 (5% future capacity increase per year). Large differences exist in the extent to which different treatments contributed to the total health losses.
Conclusions: The method sheds light on the indirect harm related to the COVID-19 pandemic. The results can be used for policy evaluations of COVID-19 responses, in preparations for future waves or other pandemics and in prioritizing the allocation of resources for capacity increases.

1. Background

The COVID-19 pandemic has greatly affected morbidity and mortality worldwide (Gebru et al., 2021; Vaughn et al., 2019; Wouterse et al., 2022). The care for patients infected with SARS-CoV-2 (COVID-19 patients) also affected access and delivery of regular care for non-COVID patients. Low-, middle- and high-income countries were confronted with disruptions in health services, where patterns by country, income or pandemic intensity were not always found (Arsenault et al., 2022). Disruptions in regular care also occurred across various sectors ranging from primary care to social services and hospital care (Johnson et al., 2021; van Giessen et al., 2020; Graham et al., 2020). Within hospital care, elective care for non-COVID patients was frequently delayed in order to minimize the risk of COVID-19 spread and because critical resources, such as personnel and materials, were needed to manage the influx of COVID-19 patients (Fu et al., 2020). In addition, patients have avoided seeking regular care because of concerns on the COVID-19 pandemic (Splinter et al., 2021). These disruptions in delivery and

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access of regular care have resulted in non-delivered care, referred to as *delayed care* in the current paper, and (temporarily) non-generated health benefits.

Although evidence on the disease burden of COVID-19 itself is accumulating (John et al., 2021; Wouterse et al., 2022; Wyper et al., 2021; Grima et al., 2021), less is known about the impact of delayed treatments for non-COVID patients. Various estimates on the quantity of delayed hospital care in numerous countries are available (Ball et al., 2020; Barach et al., 2020; Ciarleglio et al., 2021; COVIDSurg Collaborative, 2020; World Health Organization, 2021; Truche et al., 2021; Kutluk et al., 2021). Several papers have been published on the health impact of delayed urgent and semi-urgent care, such as cancer diagnoses and emergency healthcare (Ciarleglio et al., 2021; de Lange et al., 2022; Gheorghe et al., 2021; Johnson et al., 2021; Kregting et al., 2021; Nab et al., 2021; Smith et al., 2021; Toes-Zoutendijk et al., 2022). In addition to delays in urgent care, delays in elective care may have also led to non-generated health benefits. Insight into the health burden, in addition to delays, is important for policy evaluations of COVID-19 responses and for developing pandemic preparedness plans as equal declines for different healthcare interventions may lead to different health burdens. Information on the health impact could therefore aid researchers and policy makers in evaluating and preparing COVID-19 responses. The aim of the current paper is to illustrate a method for estimating the total health impact of delayed elective care from a national perspective, measured in quality-adjusted life years (QALYs). In the current paper, this method was applied to elective surgical care given the availability of national data on delivered elective surgical procedures and international literature on QALY gains of elective surgeries. In this study, the total non-generated QALYs due to delays in offering elective surgical care in the Netherlands were estimated, starting from week 11 in 2020, the week that COVID-19 was characterized as a pandemic by the World Health Organization and the first measures of containment were taken in the Netherlands, until December 31, 2021 (World Health Organization, 2020).

2. Methods

Scope The proposed method can be used to obtain a quantitative insight in the population-level non-generated health benefits due to delayed elective care during the COVID-19 pandemic. The presented method is a generic approach that can be applied to various types of delayed elective care. In the current study, the method was applied to delayed elective surgical care. (Semi-)urgent care fell beyond the scope of the study, because the medical conditions requiring such care often have a progressive nature, which could not be captured by this method. For this method, information from multiple sources about a variety of elective care was collected, including administrative data, scientific literature and interviews with medical specialists. A model was developed to link the accumulating surgical backlog to the related health impact of individual elective procedures and quantify the population-level health impact.

Model description The increased demand for care due to the COVID-19 pandemic often resulted in reduced access to elective care for non-COVID patients. Our model was based on the theory that reduced access to care without expansion of capacity leads to continuous waiting lists and accumulating backlogs (Fomundam and Hermann, 2017). We assumed that the accumulating backlog indicated unmet care needs and that the health impact could be quantified in terms of non-generated QALYs. A list of all assumptions underlying the model is shown in Table 1.

Table 1
Assumptions.

Assumptions	
Expected surgical volume:	
- The expected surgical volume for 2020 and 2021 can be estimated based on trends in historic years (2015–2019).	
- The number of surgical procedures follows a constant level, a fixed annual growth factor or a flexible pattern over time, modelled with a linear, log-linear (exponential) and a polynomial spline model of the third degree	
(Non-)generated QALYs:	
- The accumulating backlog indicates unmet care needs, which can be quantified in terms of non-generated QALYs.	
- QALYs are gained (or lost) linearly over time.	
- On average, all delay is associated with a negative QALY impact.	
- Some QALY-losses can be regenerated by increasing medical capacity and performing additional surgeries. Due to extended waiting times, QALY gains over the lifespan of patients are reduced. The fraction of QALY-losses that can be regenerated is less than one and depends on the waiting time until capacity increases. Waiting time is approximated by a first-in-first-out principle.	
- Any possible deterioration of the health status while being on the waiting list did not affect the QALY gains that could be generated by the delayed procedure.	
Prioritization:	
- Prioritization was not related to the possible QALY gain of patients being prioritized and hence the QALY gain for prioritized patients did not differ from the QALY gain for patients on waiting lists.	
Sensitivity analysis:	
Prioritization by expected outcome	- Patients who are expected to have a higher-than-average QALY gain from treatment are prioritized. Details for estimating the QALY gains are described in Appendix 3.
Prioritization by medical need	- Patients with a more severe health problems may gain fewer QALYs after a surgery as compared to the average. Details for estimating the QALY gains are described in Appendix 3.
Scenario analysis: Future capacity increases	- The number of weeks with future capacity increases equals the number of weeks during which relative production levels exceeded 100% in 2021. Future capacity increases equal to the range of realized increased production levels in 2021. - Potential future COVID waves from 2022 onwards will not lead to decreased capacity. Relative production in weeks without capacity increases is 100%. - Any future capacity increases are distributed proportionally over patient groups (no prioritization between patient groups).

2.1. Model input

Three data sources were used to obtain information about the accumulating backlog and health impact (see Fig. 1). First, the OpenDIS dataset was used (https://opendisdata.nl/), which contained administrative data on the annual volume of elective procedures at a national level before the COVID-19 pandemic (2015–2019). No individual data was collected. Surgical procedures are registered as a Diagnoses-Related Group (DRG) with various underlying care activities. Elective procedures were identified based on a nationally available urgency-classification (Nederlandse Zorgautoriteit, 2020). (Semi)--urgent surgical care, including oncology, was excluded. The selection of elective procedures was validated with medical specialists during interviews about delayed care. In total, 463 elective DRGs were included. These were registered under the following twelve medical specialties: ophthalmology, orthopaedics, surgery, ear, nose and throat care, plastic surgery, cardiology, urology, gynaecology, cardiothoracic surgery, neurosurgery, dermatology and internal medicine. Appendix 1 contains more information about the selection of elective procedures.

Second, Dutch Hospital Data (the DHD-OHW dataset) was used, containing information on the weekly total volume of surgical care activities per diagnoses delivered by a subset of 36 out of 80 Dutch hospitals (Dutch Hospital Data, 2022). The DHD-OHW dataset covered weekly information from January 1st, 2019 up to December 31st, 2021. In the Netherlands, reimbursed care is delivered in both hospitals and independent treatment centres (in Dutch *zelfstandige behandelcentra*). This dataset did not contain information on the production in these independent treatment centres. Additional data on the weekly production in independent treatment centres was obtained for 2020. Third, QALY estimates of surgical procedures obtained from the scientific literature were used.

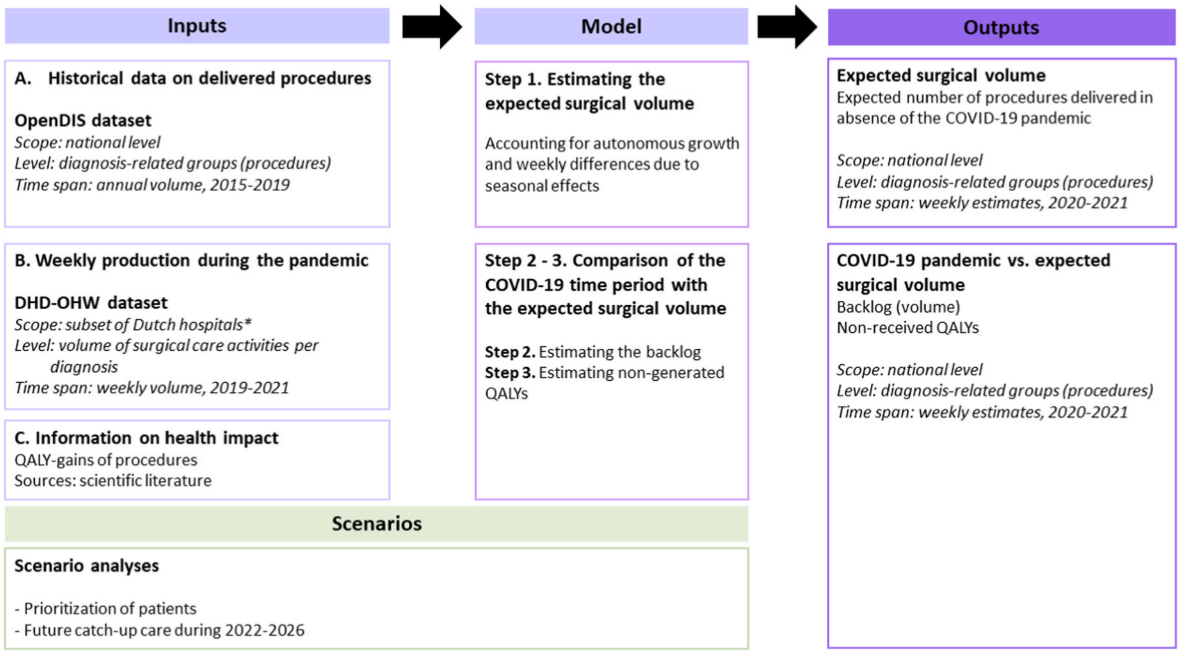

Fig. 1. Graphical overview of the model.
* This subset contained no data on production levels in independent treatment centres. Additional data on the weekly production in independent treatment centres was obtained for 2020.

The model consisted of three consecutive calculations (see Fig. 1). The first step concerned estimating the number of elective surgical procedures that were expected to be delivered in 2020 and 2021 in absence of the COVID-19 pandemic. In the second step the backlog was estimated. The *backlog* represents the net difference between the expected and actually delivered number of procedures (observed). In the third step the non-generated QALYs for these non-generated procedures were calculated.

Step 1. **Estimating the expected surgical volume** First, the expected surgical volumes for 2020 and 2021 were estimated, in hypothetical absence of the COVID-19 pandemic, using national administrative data from previous years (OpenDIS data). A revealed autonomous trend was modelled with a regression analysis with the annual number of delivered surgical procedures as dependent variable and year (2015–2019) as independent variable. It was assumed that trends in surgical procedures either followed a constant level, a fixed annual growth factor or a flexible pattern over time. As such, either a linear, log-linear (exponential), or a polynomial spline model of the third degree was selected, based on the best fit (R-squared statistic). This model was used to predict the annual expected number of surgical procedures in 2020 and 2021.

For some diagnoses, it was likely that the number of cases and the demand for surgical care decreased during the COVID-19 pandemic because of the prevention measures taken, such as social distancing. For instance, the number of childhood ear infections (otitis media) declined during the COVID-19 pandemic (Hullegie et al., 2021), which likely results in decreasing demand for otitis media surgeries (Diercks and Cohen, 2021). Medical specialists were interviewed about delayed care, including their observations with decreased demand for surgical care due to epidemiological changes during the COVID-19 pandemic. Furthermore, they were asked to give an estimation of the decline in demand. These estimates were used to correct the expected surgical volume for these surgical procedures. In our model, such corrections were made for surgical procedures for otitis media and tonsillitis (declined with 35%) and sinusitis (declined with 20%).

Subsequently, the annual volume of surgical procedures in 2019, and the expected volumes for 2020 and 2021 were converted to weekly volumes, accounting for differences in production levels during the year. These *seasonal effects* were calculated with the weekly production levels for each diagnosis in a year before the pandemic (2019). A seasonal correction factor, represented as a percentage of the annual production, was estimated using a three-week moving average.

Step 2. **Estimating the backlog** In this step, the *backlog* was calculated, representing the difference between the actual number of surgical procedures during 2020 and 2021 and the expected surgical volume (see "Step 1").

Information on the weekly number of surgical care activities delivered per diagnosis during the COVID-19 pandemic was obtained from the DHD-OHW dataset (see Fig. 1). Actual production levels of the subset of hospitals during 2020 and 2021 (corrected for seasonal effects as described above) were expressed as percentages of expected weekly production levels. These percentages were applied to the surgical volume of the full population of hospitals to render national estimates of weekly surgical hospital volumes. Separate data on the delivered surgical volume in independent treatment centres in 2020 was used and it was assumed that similar volumes were delivered in 2021. This resulted in an estimation of the nationally delivered surgical volumes during 2020 and 2021 in both hospitals and independent treatment centres. Finally, the weekly *backlog* was calculated by comparing the delivered weekly surgical volume to the expected surgical volume.

Step 3. **Estimating non-generated QALYs** The scientific literature was searched for articles reporting QALY gains of elective surgical procedures compared to conservative treatment or no treatment. Appendix 2 describes the procedure that was used for selecting QALY estimates. For each surgical procedure, a QALY estimate and the corresponding time horizon and discount rate were extracted from the literature. Next, the selected QALY estimates were re-calculated using a discount factor of 1,5% per year following Dutch guidelines for economic evaluations (Zorginstituut Nederland, 2016). Non-generated QALYs were calculated by multiplying the weekly *backlog* (see "Step 2") with the QALY estimate of each elective surgical procedure.

For some weeks during the summer of 2020 and 2021 more elective surgical procedures had been delivered than expected due to deflations of the COVID-19 pandemic and extensive efforts to catch-up delayed procedures (Nederlandse Zorgautoriteit, 2021). During the weeks in which the production level exceeded the expected volumes, additional surgeries were performed. In other words, non-generated QALYs were now being generated. Nevertheless, extended waiting times reduce QALY gains over the lifespan of patients, as they have less remaining lifespan to enjoy the benefits of a surgery. This means that the surplus in production levels was able to regain some, but not all QALY losses. Therefore, after calculating the number of additional QALYs that were gained by production surplus, a correction was applied to account for the definitive QALY loss due to the extended waiting time (we further refer to this phenomenon as a ‘QALY penalty’).

In order to estimate the QALY penalties, a fictitious pandemic-related waiting list was simulated, as the DHD-OHW dataset did not contain information on individual waiting times. The maximum extended waiting time was estimated from the weekly *backlog* and based on a first-in-first-out principle. The first week that a certain number of procedures was added to the backlog was compared with the first week until which this number of procedures was caught up. To calculate the QALY penalties, the estimated maximum waiting time (in weeks) for procedures being caught up was multiplied by the anticipated QALY gain per week. The anticipated QALY gains per week were calculated by dividing the QALY estimate by the corresponding time horizon, assuming constant QALY gains over time. The generated QALYs for procedures being caught up were then corrected for the QALY penalty, implying that the procedure, after an extended waiting time, generated a reduced number of QALYs. Finally, the assumption was made that any other consequences of waiting time, such as possible deterioration of the health status while being on the waiting list, did not alter QALY gains that could be achieved by the delayed procedure.

2.2. Sensitivity analyses

Medical specialists indicated during interviews about delayed care that various criteria were used to prioritize certain patients during periods of reduced capacity. Prioritization could mean that average QALY estimates found in the literature are not fully applicable to the accumulating backlog and that actual QALY losses deviate from mean QALY losses predicted by literature. As reliable estimates of the impact of prioritization on QALY gains could not be obtained, it was assumed that prioritization was not related to the possible QALY gains of prioritized patients and hence the QALY gains did not differ from the QALY gains for patients on waiting lists.

In a sensitivity analysis the impact of prioritization on non-generated QALYs was explored. As a lower boundary, the health impact was estimated for prioritization by expected outcome. Prioritization by expected outcome describes the situation where patients who are expected to have a higher-than-average QALY gain from treatment are prioritized (e.g., prioritizing younger patients). The backlog will consist of patients with lower-than-average QALY gains, and a lower number of non-generated QALYs is obtained. As an upper boundary, the health impact was estimated for prioritization by medical need. This describes the situations where patients with a worse health status, who may have been in a higher need of treatment, have been prioritized. Hence, it is assumed that patients with a worse health status may gain fewer QALYs as compared to the average, known as the worse in – worse out phenomenon (Röder et al., 2007). Therefore, it was assumed that patients who were prioritized had a relatively lower-than-average QALY gain (e.g., prioritizing older, frail patients). The backlog will consist of patients with higher-than-average QALY gains, and a higher number of non-generated QALYs. Appendix 3 describes how the QALY gains for prioritization situations were estimated.

2.3. Scenario analyses

During the COVID-19 pandemic, incidental capacity increases were realized. If it is possible to continue these capacity increases in the upcoming years, QALYs that have not been generated during the pandemic can still partially be generated. A scenario analysis was performed to estimate the effect of possible future capacity increases from 2022 onwards. For every diagnosis, the number of weeks per year with future capacity increases was set equal to the number of weeks during which relative production levels exceeded 100% in 2021 for that specific diagnosis. In order to not be overly optimistic about the possibility of future capacity increases, future capacity increases were defined according to the range of realized increased production levels in 2021 (see Table 1). It was assumed that there would be no more COVID waves from 2022 onwards, hence production in the weeks without future capacity increases was set at 100%. The duration of the future capacity increases scenario was set at 5 years (2022–2026). The QALYs gained during future capacity increases were corrected for QALY penalties due to the reduced life span in which patients can benefit from the QALYs gained (see Table 1).

3. Results

In the first step of the model, the expected number of surgical procedures for 2020 and 2021 was estimated at approximately 1.6 million (see Table 2). The total *backlog* amounted to 305.374 delayed surgical procedures in 2020 (from week 11 onwards) and 2021. The non-generated QALYs due to all delayed surgical procedures amounted to a total of 319,483 QALYs (see Table 2). This corresponded to a loss of 18% of the total number QALYs that were expected to be generated.

Fig. 2 shows the weekly *backlog* in surgical volume and the non-generated QALYs in 2020 and 2021. It should be noted that this figure shows the aggregated results for all surgical procedures. The patterns of production levels and non-generated QALYs may vary for each underlying individual procedure.

Fig. 2 shows that more delayed surgical procedures led to more non-generated QALYs. In a number of weeks during the summer, production levels slightly exceeded the expected volume which led to a decline in non-generated QALYs. This was not the case in some weeks (week 29 in 2020 and week 23 in 2021). Although production levels in these weeks exceeded the expected volume, certain procedures with a relatively high QALY-value were delayed, and therefore the net increased production levels did not compensate for the net QALY losses.

The results show large differences in non-generated QALYs across medical specialties, diagnoses, and surgical procedures, as depicted in Fig. 3. A higher number of non-generated QALYs was found for the orthopaedic and ophthalmology specialties, because these specialties are normally characterized by high surgical volumes and accordingly, the backlog was high. Heterogeneities in the number of non-generated QALYs were also linked to differences in QALY estimates. For instance, two types of gynaecological surgeries: endometriosis surgery and vaginal prolapse surgery, amounted to a similar number of non-generated QALYs. Interestingly, endometriosis surgery had a lower backlog but led to similar non-generated QALYs because of a higher QALY estimate compared to vaginal prolapse surgery where the backlog was larger but the QALY estimate lower (see Fig. 3, highlighted in blue).

3.1. Sensitivity & scenario analyses

3.1.1. Prioritization of patients

The total non-generated QALYs amounted to 150,973 for prioritization by expected outcome and to 488,195 for prioritization by medical need, as compared to 319,483 without prioritization for 2020 and 2021 (see Table 2).

Table 2
Results expected surgical volume, backlog and non-generated QALYs for each medical specialty[a].

Medical specialty		Expected surgical volume	Expected QALYs	Backlog	Non-generated QALYs (as percentage of expected)	
Ophthalmology		446,381	832,276	−62,295	120,069	(14%)
Orthopaedics		214,235	348,258	−48,766	84,551	(24%)
Surgery		277,261	205,103	−53,383	45,449	(22%)
Ear, nose, throat		189,696	89,294	−38,368	16,230	(18%)
Plastic surgery		128,866	84,874	−24,164	14,096	(17%)
Cardiology		85,771	117,967	−9385	13,031	(11%)
Urology		88,572	55,913	−19,704	11,060	(20%)
Gynaecology		88,381	28,422	−20,851	5623	(20%)
Cardiothoracic surgery		26,354	24,650	−4867	4291	(17%)
Neurosurgery		47,949	12,850	−12,826	3133	(25%)
Dermatology		36,181	8834	−10,685	1427	(17%)
Internal medicine		772	4981	−80	523	(10%)
Total	2020	716,906	789,723	−152,762	167,123	(21%)
	2021	913,513	1,013,427	−152,613	152,360	(15%)
	2020 + 2021	**1,630,419**	**1,813,422**	**−305,374**	**319,483**	**(18%)**
Sensitivity analysis (Prioritization)	2020 + 2021	Lower bound: prioritization by expected outcome			150,973	
		Upper bound: prioritization by medical need			488,195	
Scenario analysis (future capacity increases)	2020–2026	2% future capacity increases[b]		−293,265	311,220	
		5% future capacity increases[b]		−278,866	300,710	

[a] It should be noted that an unequal share of surgical procedures per medical specialty were included in the model, as some medical specialties contain more elective surgical procedures than others that contain more non-surgical care and/or (semi-) urgent surgical care. Given these differences, the total number of non-generated QALYs should not be directly compared between medical specialties.
[b] The number of weeks per year with future capacity increases was set equal to the number of weeks during which relative production levels exceeded 100% in 2021 for each diagnosis (see *Scenario analysis)*.

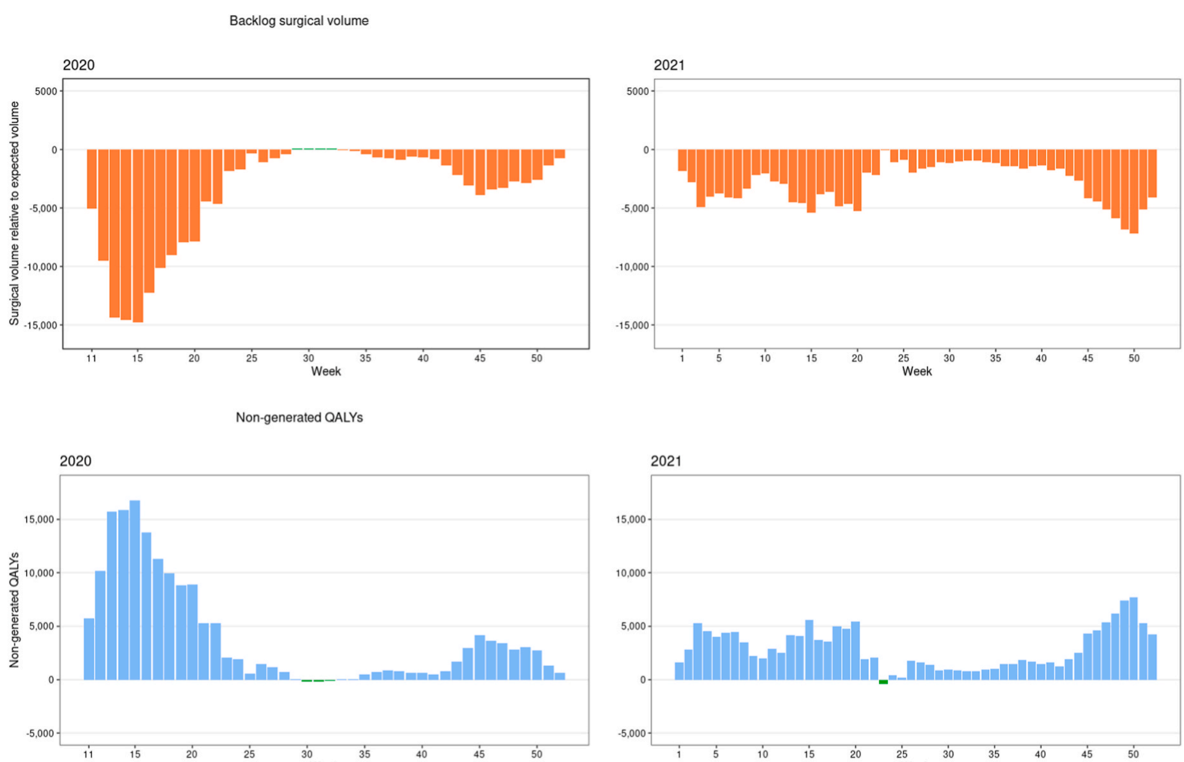

Fig. 2. Total net backlog and non-generated QALYs per week for 2020 and 2021. **Caption:** Green bars indicate values for weeks with production levels which exceeded the expected production levels. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

3.1.2. *Future capacity increases*

On average for all diagnoses, the overproduction was on average 8% in 2021. Based on these overproduction levels, scenario analyses were performed with a weekly capacity increase of 2% and 5%. In the scenarios for future capacity increases, the non-generated QALYs declined from 319,483 to 311,220 (2% future capacity increases) and 300,710 (5% future capacity increases), respectively (see Table 2).

4. Discussion and conclusions

The method presented in the current paper allowed for obtaining a quantitative insight into the population-level health losses due to delayed elective care during the COVID-19 pandemic. The method quantified non-generated QALYs due to delayed elective surgical care in the Netherlands during the first two years of the COVID-19 pandemic. A total of 305,374 delayed elective surgical procedures in 2020 and 2021

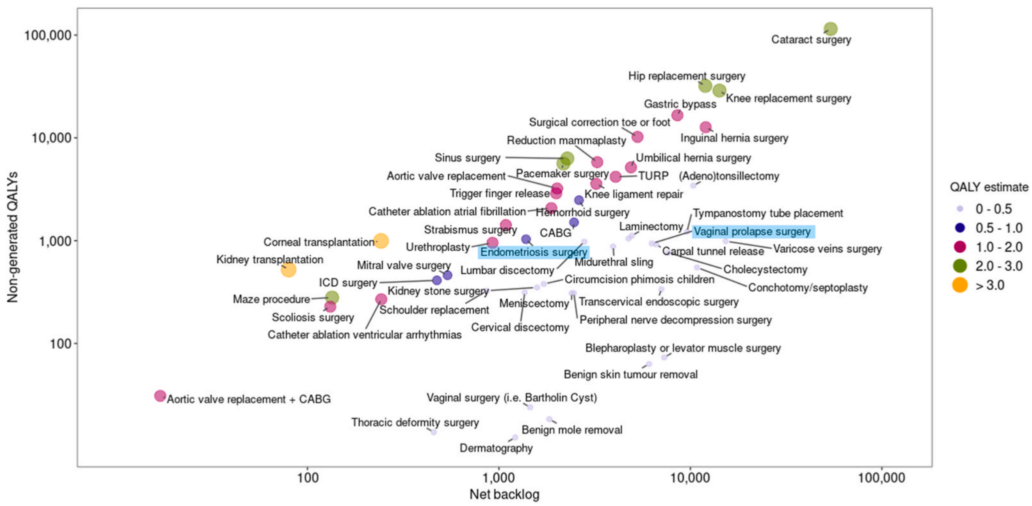

Fig. 3. Total net backlog and non-generated QALYs for each procedure*. Please note, the axes are on a logarithmic scale.* DRGs were clustered if they indicated a similar procedure, but were registered under separate DRG codes because of technical reasons (e.g., open and laparoscopic variants of the same procedures). The selected procedures and their clustering were validated with medical specialists from all twelve different medical specialties during interviews about delayed care. A full list of included procedures (DRGs) and their clustering is available upon request.

corresponded to 319,483 non-generated QALYs. This is approximately 18% of the total QALY gain that was expected to be generated in 2020 and 2021 by elective surgical procedures in a hypothetical situation without COVID-19. This shows that delayed elective surgical procedures carried a major health burden.

4.1. *Implications*

The insight into the indirect burden of delayed elective surgical care aids in quantifying the total indirect burden of the COVID-19 pandemic and could be used in policy evaluations of COVID-19 responses. In addition, the results could help develop strategies for minimizing health losses when working through the surgical backlog as well as making plans as part of future pandemic preparedness. Worldwide, extensive efforts have been made to work through the surgical backlog. Clearing the surgical backlog has serious implications for healthcare systems (COVIDSurg Collaborative, 2020; Wang et al., 2020)). It remains to be seen which production levels can be reached in the future and for how long. In a scenario analysis, the impact of future capacity increases on population health losses was explored. This showed that complete reduction of the backlog is rather unlikely and there are limits to the extent that additional capacity can regain non-generated QALYs. Additional strategies are warranted to minimize the existing health losses and prevent future population health losses.

The results showed that non-generated QALYs were high when many procedures were delayed or cancelled, and/or when QALY gains of surgical procedures were high. Measures for limiting the health burden could therefore focus on maintaining elective surgical volume and maximizing health effects through prioritization. Regarding surgical volume, our results showed a large variation in the backlog across different elective procedures and over time. This variation over time corresponds to the findings for other countries (Uimonen et al., 2021; Truche et al., 2021; Arsenault et al., 2022) did not find a clear pattern in health service decline by pandemic intensity. The variation in backlog across elective procedures can inform the planning of surgical activity and shows which surgical care needs specific attention. Two examples of such planning would be transferring elective care to independent treatment centres that have not been overwhelmed by COVID-19 patients or optimizing operation room schedules (Macdonald et al., 2020; Naderi et al., 2021).

Next to the backlog per elective surgical procedure, the information on the associated health impact can be used for optimizing planning based on health effects. Prioritization based on health effects could include identifying and prioritizing those patients with the highest expected outcome for each procedure. The sensitivity analyses indicated that population health losses may be greatly dependent on the specific prioritization grounds that are applied in clinical practice, and that prioritization based on expected outcome may contribute to minimizing population health losses. We suggest to also look at prioritization of elective surgical procedures with the highest QALY gains across medical specialties, which was also recommended by several others (Gravesteijn et al., 2021; Rovers et al., 2022). The results of the current study show the variety in QALY-impact between a wide range of elective surgical procedures, and could be used as a starting point for reaching consensus on prioritization based on health effects between specialists. Moreover, prioritization based on health effects has to be weighed against the relative importance of other factors and considerations such as urgency, waiting time, patient preferences, solidarity and fairness. Recently, several attempts have been made to reach consensus on the use of different prioritization criteria and the operationalisation in clinical practice (Bouthillier et al., 2021; Valente et al., 2021; van der Horst et al., 2022). Further research on the implementation and impact of prioritization on health effects is needed to assess its feasibility and value. Reaching consensus on prioritization remains of utmost importance for optimizing health effects during periods with scarce available resources.

4.2. *Strengths and limitations*

The method presented in the current study was developed for estimating the health impact associated with delays in elective care. By using a general approach, the method provides insight into the population health impact of delayed care for numerous elective procedures. The model could also be extended to other care types and to other countries if sufficient data is available. This would allow for making cross-country comparisons, on the relations between the type of COVID-19 responses, the magnitude of healthcare disruptions and the associated health burden. Cross-country comparisons, including countries from various income groups, are recommended to get a comprehensive understanding of the impact of a pandemic. In contrast to other models estimating the health impact of delays in (semi-) urgent care, such as cancer surgery and emergency healthcare (de Lange et al., 2022; Gheorghe et al., 2021; Gravesteijn et al., 2021; Nab et al., 2021; Smith et al., 2021), our model focused on elective hospital procedures and therefore did not require detailed model inputs to account for disease progression and alterations of the treatment pathway. As we aimed to arrive at nationwide estimates about the impact of delayed elective surgical, several methodological challenges had to be met. These challenges related to the availability of several model inputs and their level of detail. The general approach that was chosen to handle some of these challenges, for example related to the selection of elective surgical procedures, is described in Appendices 1-3. Here we discuss limitations regarding the developed model and some of the underlying assumptions.

Surgical activity during the pandemic was compared to the expected volume of surgical procedures, which was predicted by estimating an autonomous trend based on five previous years (2015–2019). In addition to autonomous growth, the expected volumes may have been influenced by other factors during the pandemic. The expected number of certain treatments, such as Tympanostomy tube placement for otitis media, are likely to have been affected by the measures taken during the pandemic. For example, distancing measures and lockdowns of schools and sports facilities may have led to fewer infections and injuries. Although we corrected for these expected declines based on declines reported by medical specialists during interviews, it is likely that not all declines were identified and uncertainty exists around the declines and expected numbers. Therefore, validation of these estimates is recommended. Furthermore, there were some limitations regarding the QALY losses that were estimated in the model. As empirical evidence on patient's health status before and after delayed care was not (yet) available, we had to make the assumption that the health burden caused by delayed elective care is approximated by backlog and the average QALY gain of surgical procedures as reported in the international literature. The QALY-values that were obtained were not always fully applicable to the heterogeneous patient population, which may result in some biases regarding the real health impact. For example, specific procedures are often compared to conservative treatment regimens, which can be country specific and may not always be comparable to the Dutch context. In our approach, a lifetime estimate of QALY gains would be preferable in light of comparing the QALYs foregone for many different surgical procedures, but many studies used much shorter time horizons. For some surgical procedures no literature on QALY gain was found and QALY-values for other procedures were applied that had similar QALY gains according to medical specialists. Finally, as neither information on the distribution of QALY gains nor information on the individual waiting times was available, the assumption had to be made that health benefits of treatments are linearly distributed over time. However, this may not hold for all treatments, for example when surgery yields more benefits short after treatment as compared to further in the future. In these situations, the estimated QALY-losses may have been biased depending on the QALY distributions and the respective individual waiting times.

In addition to the information on QALY estimates, some assumptions on the health impact of delayed care have to be discussed. First of all, it was assumed that prolonged waiting only affected QALY gains because of a reduced lifespan during which patients can enjoy benefits from a procedure. Any other effects of waiting time on health status and QALY gains were not included in our analysis, as conflicting evidence had been found in the literature. Various studies did not find a clear effect of waiting time on postoperative health status (Ostendorf et al., 2004; Tuominen et al., 2010)), while others found that waiting time was associated with a poorer health after surgery (worse in – worse out) (Clement et al., 2021; Lebedeva et al., 2021; Röder et al., 2007; Vergara et al., 2011). T is likely that the prolonged waiting times during the pandemic have led to additional health losses, for example due to disease progression or premature death. It was also assumed that all delayed care was associated with negative health effects (non-generated QALYs). It is, however, possible that patients may no longer seek treatment because conservative treatment has fulfilled their needs. This may be more likely for some procedures (e.g., herniated disc surgery) than for others. This may also indicate that delaying or cancelling certain treatments would have no negative health effects or could even have a positive effect on some patients if they are prevented from risks related to overtreatment (Moynihan et al., 2021). Future research on these mechanisms is recommended in order to gain a better insight into the long-term population health losses. Finally, as this model was based on national level data, the presented results do not give insight into differences between patients or patient groups. Further research with individual-level data is recommended to provide insight into inequalities in the delay of care and corresponding health effects.

5. Conclusion

The presented method sheds light on the indirect harm related to disruptions in elective care provision during the COVID-19 pandemic. With the availability of local or national data on delayed care, the developed model can be used by others to quantify non-generated QALYs for various types of elective care. The results can be used in cross-country policy evaluations of COVID-19 responses or can be used to prepare an adequate allocation of hospital resources in a new wave of this or other pandemics. Finding ways to minimize the major health burden due to delayed elective care as shown in this study is important from both a societal perspective, as well as for all the individuals that have been confronted with delays in their care during the COVID-19 pandemic.

Credit author statement

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Data availability

This study involved third party data. The OpenDIS dataset was used, which is publicly available from: https://opendisdata.nl/. In addition, aggregated Dutch Hospital Data and aggregated data on production levels in independent treatment centres were used, which was made available through a third-party source, the Dutch Health Authority (Nederlandse Zorgautoriteit).

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Appendix 1. Selection of elective care

In this paper, an estimation of the health impact of delay was made for elective surgical procedures. The following criteria were applied to select elective surgical care for inclusion in the analysis. It should be noted that the feasibility of using these criteria depends on the availability of country-specific data sources.

Criterion 1. Exclusion of (semi-) urgent care including cancer care

The focus in this model is on elective care. Many classification systems are available (American College of Surgeons, 2020a; American College of Surgeons, 2020b; Nederlandse Zorgautoriteit, 2020). To determine which care is elective, in the current paper, the urgency coding system of the Dutch Health Authority was used (Nederlandse Zorgautoriteit, 2020). In this coding system treatments for certain conditions, as registered by Diagnoses-Related Group (DRG), are labelled by urgency of care with the following labels: <24 h, <1 week, <2 weeks, <1 month, <2 months, <3 months, and >3 months. Based on different medical triage classifications, DRGs that can be performed >1 month (with labels: <2 months, <3 months and >3 months) were considered elective, DRGs with more urgent labels were excluded (Federatie Medisch Specialisten, 2020). DRGs that did not have a label were also excluded. Most oncological diagnoses were excluded as they were classified as being acute or critically plannable. Remaining oncological diagnoses were also excluded because of the progressive nature of oncological diagnoses and because the model did not allow for estimating the health impact associated with progressive diseases. Oncological care was excluded by excluding diagnoses with key words related to oncologic diagnoses, such as "tumour, malign*, carcin*, lymphoma, myeloma, neoplas*, oncolog*, hodgkin, leukemia, metastas*, hnpcc, neuroblastoma, radiotherapy".

Criterion 2. Exclusion of non-surgical care

More specifically, the model focuses on surgical procedures in contrast to other types of care (e.g., outpatient visits or drug treatments), because data on surgical volume and corresponding QALY estimates were available and elective surgeries were frequently delayed. Surgical procedures were identified within the data based on a list of declaration codes that was provided by the Dutch Health Authority (NZa). If sufficient data is available, the model could be extended to other forms of elective care, for example drug treatments.

Criterion 3. Exclusion of secondary procedures

Secondary procedures were excluded because the QALY gains of treatments often refer to a combination of primary and possible follow-up procedures. Secondary procedures were excluded by excluding diagnoses with key words related to secondary procedures, such as "implant failure" and "posterior capsular opacification".

After applying the selection criteria, a list of included diagnoses was shown to medical specialists. Based on this validation with medical experts, some surgical procedures were added to the selection because these were incorrectly excluded. For example, a number of procedures with missing urgency labels were added to the selection as medical specialists indicated that the procedures were elective. A full list of included diagnoses and procedures (DRGs) is available upon request.

Appendix 2. Selection of literature on the health impact of surgical procedures

To estimate the health impact of delayed surgical procedures during the COVID-19 pandemic, Embase, PubMed or Scopus, the Tufts Cost-Effectiveness Analysis (CEA) Registry (Center for evaluation of Value and Risk in Health (Center for Evaluation of Value and Risk in Health CEVR, 2019), and Google Scholar were searched for articles reporting the QALY gain of the surgical procedures included in the model. Used search terms are displayed in Table 1.

Table A1
Used search terms

Surgical procedure	Disease	QALYs
Varying, informed by Dutch medical guidelines (Federatie Medisch Specialisten, n.d.)	Varying, informed by Dutch medical guidelines (Federatie Medisch Specialisten, n.d.)	QALY Quality-adjusted life years Cost-effectiveness Cost-utility Quality of life Utility value/score

Based on the following selection criteria (in order of importance), the best scientific article available was selected for each surgical procedure:

1. Best suited to the disease and surgical procedure included in the model:
   - Same or similar patient group
   - Same or similar procedure
2. Preference for studies reporting QALY gains in comparison to conservative treatment or medication.
   - If not available: before-after comparison
3. Preference for studies from the Netherlands, followed by studies from OECD countries.
4. Preference for studies with longer time horizons
5. Preference for studies of high quality:
   - Quality of life measured using a validated questionnaire/measurement method
   - Larger sample sizes
   - In case of a model-based economic evaluation: validated model or a model of sufficient quality
   - In case of data collection: limited risk for selection bias
6. Preference for more recent studies compared to older studies

If no QALY gain was found for a certain procedure, a QALY gain for a reasonably similar procedure (in terms of QALY gain) was used. This was validated with a medical specialist familiar with the different procedures. If such a similar estimate was also not available and the QALY gain of a procedure was expected to be quite small, a conservative QALY gain of 0.01 with a time horizon of 5 years was used, which is equal to the lowest found QALY-value included in the model. This was the case for four different surgical procedures. If a QALY gain and a similar estimate were not available but the QALY gain was not expected to be small, medical specialists were asked to name a different procedure with similar QALY gain. This was the case for seven different surgical procedures.

Since it was not feasible to obtain QALY estimates for all elective surgeries, including those less-frequently performed, a general approach was chosen. For the majority of delayed elective surgeries (up to 70% of total delay in each specialty) QALY estimates were searched in the literature. For the remaining 30% an average QALY estimate was used, based on the QALY estimates that were already included.

A full list of included QALY estimates is available upon request.

Appendix 3. Sensitivity analyses for prioritization of patients

The potential impact of prioritization of patients on QALYs was explored for two situations: prioritization by expected outcome and prioritization by medical need. It was assumed that the QALY gains as reported in the literature followed a left truncated normal distribution, implying that negative QALY gains do not occur. A normal distribution was created based on the mean and standard deviation that were derived from the literature with a left tail truncation at a QALY value of zero and a right tail truncation of the same distance as the left truncation to arrive at the average QALY gain (see Figure A1). When a standard deviation was not reported, it was either estimated from the 95% confidence interval and the sample size or from the standard error and the sample size. When no information on the distribution was reported, the standard deviation was imputed based on the reported average QALY gain and estimated interquartile range:

$$SD = \left(\frac{QALY\ estimate - 0}{2}\right) * \frac{3}{1.35}$$

For prioritization by expected outcome (higher than average QALY gain), it was assumed that the proportion of treated patients corresponded to the rightmost proportion of the QALY-distribution. For example, for a weekly relative production level of 80%, a truncation was defined by the upper 80% of the distribution (Figure A1- Panel A). Alternatively, for prioritization by medical need (lower than average QALY gain), the truncated distribution was defined by the lower 80% of the normal distribution (Figure A1, left side). The corresponding mean value for these proportions was generated from the truncated normal distribution (R package: etruncnorm). For weeks with a relative production level above 100%, it was assumed that patients who were caught up were those that had not been prioritized during weeks with delays. Hence, it was assumed that those patients had a mean QALY gain based on the opposite side of the truncated distribution of the prioritized patients (Figure A1 – Panel B). These adjusted average QALY gains were multiplied by the surgical volume, and QALY penalties were applied for weeks with production levels above 100%.

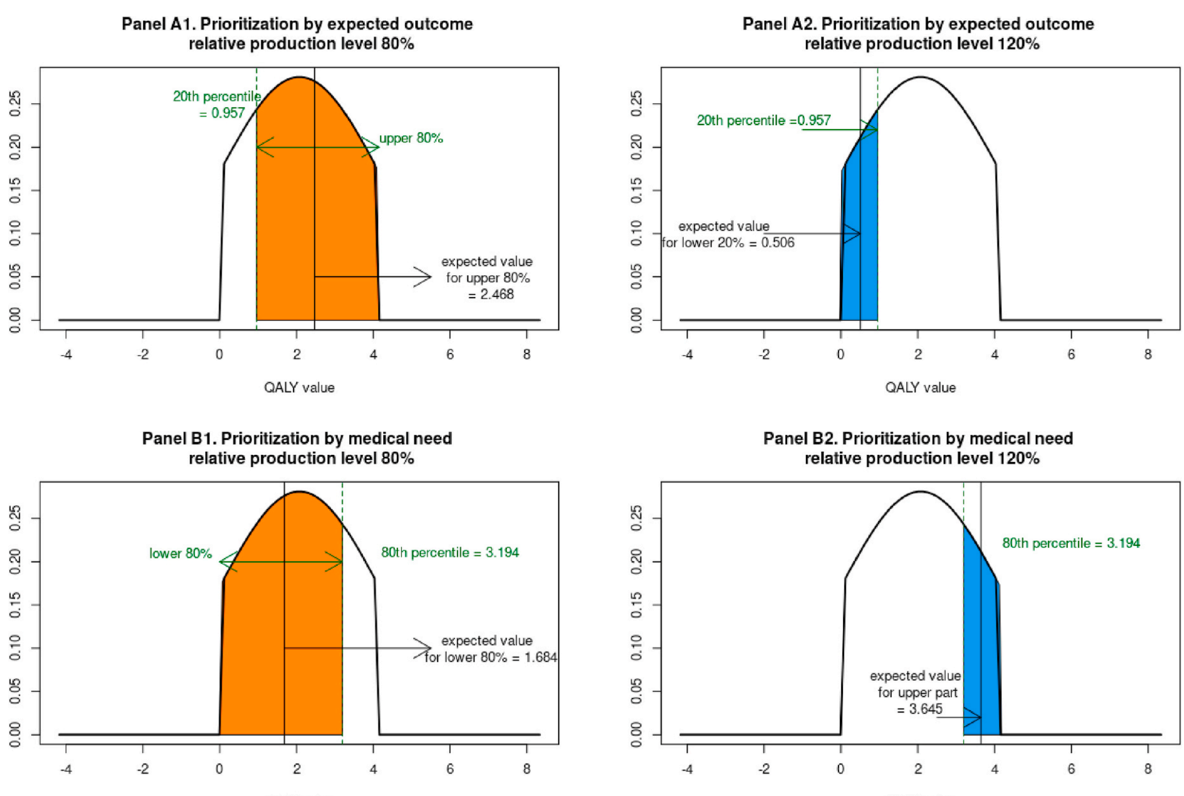

Fig. A1. Example of a truncated simulated normal distribution for prioritization by expected outcome (Panel A) and medical need (Panel B).

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