BMJ Open

Lessons learned from cancelled elective surgeries during the COVID-19 pandemic: development of a framework to prioritize OR capacity

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2021-054110
Article Type:	Original research
Date Submitted by the Author:	15-Jun-2021
Complete List of Authors:	Rovers, Maroeska; Radboudumc, Operating Rooms and Health Evidence Wijn, Stan; Radboudumc, Operating Rooms Grutters, Janneke; Radboudumc, Health Evidence & Operating Rooms Metsemakers, Sanne; Radboudumc, Operating Rooms Vermeulen, Robin; Radboudumc, Operating Rooms Van der Pennen, Ron; Tweesteden Hospital Location Saint Elisabeth Berden, Bart; Elisabeth-TweeSteden Ziekenhuis Gooszen, Hein; Radboudumc, Operating Rooms - Evidence Based Surgery Scholte, Mirre; Radboudumc, Operating Rooms Govers, Tim; Radboudumc, Operating rooms
Keywords:	COVID-19, HEALTH ECONOMICS, Health economics < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, Organisation of health services < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, SURGERY

SCHOLARONE™
Manuscripts

Lessons learned from cancelled elective surgeries during the COVID-19 pandemic: development of a framework to prioritize OR capacity

Authors:

Maroeska M. Rovers[1,2], Stan R.W. Wijn[1], Janneke P. Grutters[1,2], Sanne Metsemakers[1], Robin Vermeulen[1], Ron van der Pennen[3], Bart Berden[3,4], Hein G. Gooszen[1], Mirre Scholte[1], Tim M. Govers[1]

Collaborators/acknowledgements:

Charlotte Michels[5,6], Milica Jevdjevic[7], Ilse Spenkelink[8], Niels van den Berkmortel[2], Casper Tax[9], Michiel Sedelaar[10], Camiel Rosman[11], Sebastiaan van der Goes[12], Tony van Tienen[13], Rudolph Poolman[14], Jelle Ruurda[15], Niek Stadhouder[16], Paul van Leest[3].

1. Department of Operating Rooms, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.
2. Department for Health Evidence, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.
3. Elisabeth Tweesteden Hospital, Tilburg, The Netherlands.
4. IQ healthcare, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands
5. Department of Urology, Rijnstate Hospital, Arnhem, The Netherlands.
6. Department of Operating Rooms, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.
7. Department of Dentistry-Quality and Safety of Oral Healthcare, Radboud University Medical Center, Radboud Institute for Health Sciences, Nijmegen, The Netherlands
8. Department of Radiology, Nuclear Medicine and Anatomy, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.

9. Department of General Surgery, Haaglanden Medical Centre, The Hague, The Netherlands.

10. Department of Urology, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.

11. Department of Surgery, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.

12. Department of Orthopedics, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.

13. Orthopedic surgeon, Laurentius hospital Roermond

14. Department orthopedics, LUMC and OLVG, The Netherlands

15. Department of Surgery, University Medical Center Utrecht, The Netherlands

16. National Institute for Public Health and the Environment, PO Box 1, 3720 BA, Bilthoven, Netherlands

Correspondence to: M M Rovers, Radboud university medical center, Department of Operatng Rooms, route 715, PO Box 9101, 6500 HB Nijmegen, the Netherlands

E: Maroeska.Rovers@radboudumc.nl, T: +31-24-3651567

Abstract

Objective: To develop a prioritization framework to support priority setting for elective surgeries after COVID-19 based on the impact on patient well-being and cost.

Design: We developed decision analytic models to estimate the consequences of delayed elective surgical procedures, taking into account health impact and cost. These two measures were combined to calculate net monetary losses per week delay, which quantifies the total loss for society expressed in monetary terms. Net monetary losses were weighted by operating times. The results are presented in an online framework (https://stanwijn.shinyapps.io/priORitize/), which can be tailored to individual centres. As an example, the framework was applied to a large hospital in the Netherlands.

Results: To illustrate the framework, we studied 13 common elective procedures from four different specialities. The highest loss in quality of life due to delayed surgery was found for total hip replacement (utility loss of 0.27, i.e. 99 days lost in perfect health); the lowest for arthroscopic partial meniscectomy (utility loss of 0.05, i.e. 18 days lost in perfect health). Costs of surgical delay per patient were highest for bariatric surgery (€31/pp per week) and lowest for arthroscopic partial meniscectomy (-€2/pp per week). Weighted by OR time bariatric surgery provides the most value (€1.19/pp per OR minute), arthroscopic partial meniscectomy provides the least value (€0.34/pp per OR minute). In a large hospital the net monetary loss due to prolonged waiting times was €700.840 after the first COVID-19 wave, an increase of 506% compared to the year before.

Conclusions: This surgical prioritization framework can be tailored to specific settings to support priority setting for delayed elective operations during and after the COVID-19 pandemic, both in and between surgical disciplines. In the long-term, the framework can contribute to the efficient distribution of OR time and will therefore add to the discussion on appropriate use of health care budgets.

Strengths and limitations of this study

- We developed an evidence-based a surgical prioritization framework that can be used to support priority setting for delayed elective operations during and after the COVID-19 pandemic.
- The framework is also available via an online tool (https://stanwijn.shinyapps.io/priORitize/), that can easily be adapted according to local settings (e.g. regarding operation times) and new available evidence
- Since high-quality data regarding the consequences of the delay of surgery on deterioration are lacking, this could not be included in our model.
- We used average data from literature rather than patient-level data, which could impact the applicability of our results to the individual patient.

Keywords

COVID-19, cancelled elective surgeries, OR capacity, OR prioritization, quality of life, cost, online framework

Word count abstract: 362

Word count main text (Background through Conclusions): 3985

Introduction

The extent to which the ongoing COVID-19 pandemic is disrupting global health, social welfare and the economy is unparalleled in modern history.[1] Due to this pandemic, hospitals, continue to have to drastically reduce elective surgeries. Current estimates suggest that worldwide more than 2 million operations per week have been cancelled during the first wave of this pandemic, and most of them comprise elective surgeries.[2,3] It was also estimated that if countries increase their usual surgical volume by 20 percent after the pandemic, it would take about 45 weeks to clear the backlog due to the disruption.[2] With the current second wave and third waves, the number of delayed elective operations will only increase further. This not only affects the surgical disciplines, but also other related disciplines like gastroenterology, internal medicine, oncology, cardiology, neurology and general practitioners as they see the rise in time for referral of patients for surgery.

The word “elective” implies that the indication for surgery is not ‘acute and life-saving’ like in the case of life-threatening emergency. In most hospitals ‘acute’ cases have been scheduled without restriction during the pandemic. For the elective cases, it is likely that their suboptimal health status persisted during the extended waiting period, but there might also be patients where the delay to surgery may lead to deterioration of the disease and limit treatment options. However, it is also conceivable that their symptoms decrease during their extended waiting period, without affecting their personal life much, ultimately leading to cancelling of surgery.

The COVID-19 pandemic provides a unique opportunity to study these effects of delay of elective surgeries. Moreover, the discussion on healthcare interventions where scientific support for addition of value is limited or even lacking, has also been reopened. That is, healthcare professionals also have a responsibility to contribute to the affordability and accessibility of the healthcare system as a whole.[4,5] If healthcare can be made more sensible and qualitatively better, we can deliver more health care for less money. This requires not only a new mindset, but also reliable models and data to quantify the consequences of delay or even cancellation of surgery on patients and society.

Models like ours will help to build an evidence-based framework which can be used to support priority setting for elective surgeries and subsequent optimisation of OR capacity. Therefore, our aim was to develop a framework to support priority setting for elective surgeries based on the impact on patient well-being and cost.

Methods

Decision analytic models were developed to estimate the consequences of delaying multiple elective surgical procedures, taking into account health impact and cost. The final framework, including all individual models, provides information on relevant factors that should be taken into account when prioritizing operations, i.e. loss in health-related quality of life (HRQoL), healthcare costs due to delay and the duration of the operation. We used data from available literature to calculate expected health loss and costs due to delay of surgery.

Selected elective procedures

In consultation with clinical experts, 13 examples of elective operations that had to be delayed and represent useful examples of clinical dilemmas in times of COVID-19 were chosen. Elective Surgeries were selected based on the urgency categories of the Dutch Healthcare Authority during the early phase of the COVID-19 pandemic.[6] We sorted surgeries that could wait for at least 2 months after diagnosis. We decided to compare procedures within and between specialties to demonstrate how to prioritize within and between disciplines. The following elective procedures were included: general and gastrointestinal surgical procedures (inguinal hernia repair, laparoscopic sleeve gastrectomy (LSG), Roux-en-Y laparoscopic gastric bypass (LRYGB), partial colectomy for non-acute Crohn's disease & ulcerative colitis, sphincteroplasty), urological/gynaecological procedures (male sling procedure, tension free vaginal tape procedure), orthopaedic procedures (total hip replacement, total knee replacement, total shoulder replacement, arthroscopic partial meniscectomy), and one otorhinolaryngological procedure (septoplasty) (Table 1).

[insert Table 1]

Data acquisition and validation

For each case, input regarding cost and quality of life was derived from recent literature via systematic literature searches in PubMed. Keywords included the disease of interest, the type of surgery, length of stay, costs (resource use / healthcare utilization) and quality of life. The search strategy can be found in Appendix 1. Ideally, a randomized controlled trial (RCT) or meta-analysis of multiple RCT's comparing surgery to watchful waiting or non-surgical care, was used to inform the model. If these were not available, alternative high-quality data sources, such as observational cohort studies or equivalent alternatives, were retrieved. If studies comparing surgery to watchful waiting or non-surgical care were not available, before and after surgical studies were used to estimate the effect of postponing surgery. The quality of the studies was assessed using a checklist in which we scored the validity of the operation times and utilities used. To validate our data, we also compared them with data from the Dutch National Institute for Public Health and the Environment (RIVM) that studied the consequences of delayed surgery for the Dutch government.[7]

Quality of life

Effectiveness was measured in terms of utility values, which reflects health-related quality of life on a 0-1 scale, with 0 representing death and 1 representing full health. Utility values were derived from the EQ-5D.[8,9] When available, differences in utilities between surgery and watchful waiting were extracted at 6-12 months intervals to calculate the surgery associated gain in utility. If a watchful waiting cohort was not available, the baseline utility (measured before surgery) of surgical patients was taken to calculate the surgery-associated gain in utility. We assumed that the surgery-associated gain in utility represents the loss in utility due to delay of surgery. That is, if an operation that increases a patients utility with 0.2 is postponed for one year, we assume a total loss of quality of life of 0.2 over that year.

Costs

The extra health care expenditure due to waiting for surgery was determined by calculating the difference in healthcare expenditure before and after surgery. Only costs from a healthcare perspective were included, e.g. extra visits to the hospital, general practitioner, physiotherapist. To enable a comparison between procedures we extracted the resource use (e.g. number of extra hospital visits) rather than the actual cost from literature. The resource use was multiplied by standard unit prices for each procedure, ensuring a similar calculation of costs across operations. When available, unit prices were derived from the Dutch guideline for costing research.[10] Otherwise, unit prices were obtained from hospital fees. We excluded medication costs since this was often not reported or the reporting lacked detailed information necessary for our model. Costs were calculated in Euros (€) and based on the 2019 price level.

Operating time

Operating time was considered to be the total time the patient was in the operating theatre, including anaesthesia and surgery (skin-to-skin) time, and was extracted from literature. To validate these data, we compared them with the empirical data provided by two hospitals. Furthermore, in the online available framework, the operating time can be adjusted to match operating times for a specific setting.

Analysis

We calculated the loss of quality of life (in utilities) and extra costs per week delay of surgery. We also calculated the net monetary loss, which is defined as the total loss of waiting another week for surgery, expressed in monetary terms. The net monetary loss is calculated by multiplying the loss in quality of life due to waiting one week for surgery by a threshold value, and subsequently the extra costs of waiting another week for surgery are added. We used a threshold value of €20,000 per year of full health, as recommended for conditions with a relatively low burden of disease by the Dutch guidelines for cost-effectiveness.[10] As an example, let's assume a surgical procedure leads to a 0.2 gain in utility and a decrease in the patient's healthcare expenses of €50 per week. Delaying this procedure for one week results in a net monetary loss of $\left(0.2 \times {}^{1}/_{52} \times €20.000\right) + €50 = €127.$ The procedure with the highest net monetary loss therewith provides the most 'value' when prioritized. Subsequently, we also took into account the operating time since more patients can benefit from procedures with short operating times given a fixed OR capacity. For example, when a surgical procedure "X" can be performed twice in the timeframe of procedure "Y", procedure "Y" has to result in twice as much value to have a similar value in the same OR time. Therefore, the net monetary loss per week was weighted for the operating time, resulting in the net monetary loss per week per OR minute.

Last, we calculated the impact of postponing these elective surgeries during one of the COVID-19 waves, assuming 30% delay in these 13 elective surgeries over a 3 month period as compared to the year before. We calculated the impact of postponing elective surgeries in total costs and total net monetary loss.

Empirical example

To illustrate how our framework works and can be used in clinical practice, we applied it on real world data from a large regional hospital in The Netherlands. Data used from this hospital comprise the actual numbers of patients waiting for each of the 13 included procedures on June 30 in 2020, 2019 and 2018 and the average waiting time for each procedure in these years. Based on these data we calculated the total net monetary loss after the first COVID-19 wave (June 30, 2020) as compared to 2019 and 2018. This was done by multiplying the number of patients that are waiting by the average waiting time and the net monetary loss for that procedure.

Interactive surgical prioritization framework

The decision-analytic models for the elective surgical procedures were wrapped in an interactive web-based framework developed to further stimulate engagement and discussion between the relevant stakeholders, i.e. surgical disciplines, anaesthesiology, other referring medical disciplines, and decision makers. By default, the interactive framework shows the results presented in this paper, but users of the framework can alter some of the parameters (e.g. the operation time) or select procedures relevant to their departments or strategy. In this way the framework can be used on different strategic levels, i.e. department level or hospital level (for decisions across departments). The framework was built using R (version 4.0.2, The R Foundation for Statistical Computing, Vienna, Austria) with shiny (version 1.5.0) and shinydashboard (version 0.7.1) packages.[11,12] The interactive framework is available via https://stanwijn.shinyapps.io/priORitize/

Results

Quality of life

The highest loss in quality of life due to delayed surgery was found for total hip replacement (utility of 0.27, i.e. 99 days lost in perfect health when waiting for a year), followed by total shoulder and knee replacement (utilities of 0.22 and 0.22, i.e. 80 days lost in perfect health when waiting for a year), respectively (Table 2). The lowest loss in quality of life was found for arthroscopic partial meniscectomy (utility of 0.05, i.e. 18 days lost in perfect health when waiting for a year), see also Figure 1. For sphincteroplasty, the male sling procedure, and the tension-free vaginal tape procedure utility values were not available in literature.

[insert Table 2]

[insert Figures]

Cost

Delay of both LSG and LRYGB bariatric surgery resulted in the highest costs (€31 pp per week), followed by partial colectomy for non-acute Crohn's disease (€17 pp per week), and ulcerative colitis (€16 pp per week). Delay of arthroscopic partial meniscectomy was found to result in the lowest costs (-€2 pp per week), see also Figure 2. For sphincteroplasty, total shoulder replacement, male sling procedure, and tension-free vaginal tape procedure, no literature was available to determine the extra resource use due to waiting for surgery.

Net monetary loss

Combining the loss in quality of life and extra costs resulted in a calculation of the net monetary loss per week. Total hip replacement was found to result in the highest loss per week of delay (€114 per week per procedure), followed by total knee replacement (€95 per week per procedure), and partial colectomy for non-acute Crohn's disease (€94 per week per procedure). Arthroscopic partial meniscectomy appears to result in the lowest loss per week (€18 per week per procedure), see also Figure 3. It should be noted that the net monetary loss could only be calculated for procedures for which we could find information regarding the quality of life and costs in the literature.

Net monetary loss weighted by operating time

When the OR time per procedure is taken into account, the net monetary loss per week per OR minute shows that LSG provides the most value (€1.2 per week per OR minute), followed by LRYGB (€0.9 per week per OR minute), and total knee replacement (€0.9 per week per OR minute). Arthroscopic partial meniscectomy seems to provide the least value (€0.3 per week per OR minute), see also Figure 4.

Impact of surgical delay

For the 13 included elective surgeries, we conservatively estimated that 30% was delayed for 3 months as compared to the total number that was performed in the year before Covid-19 (i.e. 27,500 elective surgeries for the 13 included procedures). In total, a 30% delay in the 13 selected elective surgical procedures resulted in €0.3 million extra costs for the healthcare system and a total impact on both cost and quality of life of €3.6 million. The impact of a 10 to 50% surgical delay for each procedure can be found in Appendix 2.

Empirical example

The impact of the COVID-19 crisis was clearly visible in the surgical waiting times of a large regional hospital in The Netherlands (Appendix 3). After the first COVID-19 wave (i.e. on June 30, 2020), 624 patients were waiting for one of the 13 included procedures, while on the same day in 2019 and 2018, 291 and 257 patients were waiting. As a consequence, the total net monetary loss after the first wave was €873.504, while the total net monetary losses were €172.664 and €124.224 in 2019 and 2018. Compared to June 30, 2019 and 2018, the total net monetary after the first wave increased with 506% (€700.840) and with 703% (€749.280), respectively.

Discussion

We developed a surgical prioritization framework that provides information that can be used to set priorities in elective surgeries. For example, the highest loss in quality of life due to delayed surgery was found for total hip replacement (utility of 0.27, i.e. 99 days lost in perfect health when waiting for a year); the lowest for arthroscopic partial meniscectomy (utility of 0.05, i.e. 18 days lost in perfect health when waiting for a year). Costs of surgical delay were highest for LSG and LRYGB (€31/pp per week) and lowest for arthroscopic partial meniscectomy (-€2/pp per week). Total hip replacement and total knee replacement resulted in the highest net monetary losses per week (€114 and €95, respectively), while septoplasty and arthroscopic partial meniscectomy had a net monetary loss per week of €22 and €18, respectively. In case we assumed that 30% of the 13 included procedures were delayed over a 3 month period as compared to the total numbers of procedures performed a year earlier, the delay resulted in €0.3 million extra costs for the Dutch healthcare system and a total impact on both cost and quality of life (net monetary loss) of €3.6 million. Data from a large regional hospital in The Netherlands show that more than twice as many patients were waiting for one of the 13 modelled operative procedures after the first COVID-19 wave as compared to 2019 (624 versus 291 patients, respectively). Consequently, the extra net monetary loss caused by these waiting times was €700.840, which is an increase of 506% compared to 2019.

Several other models to study the effect of delayed surgery and to inform surgical recovery plans have been developed. Degeling et al. for example,[52] developed a model to estimate the impact of delayed cancer diagnosis and treatment on survival outcomes and healthcare costs based on a shift in the cancer disease stage at treatment initiation. They showed that a conservative 3-month delay in cancer diagnosis and treatment due to the COVID-19 pandemic, results in an excess health cost of $12 million in Australia over 5 years for the in 2020 diagnosed patients for 4 cancers. Gravesteijn et al.[53] also developed a model that supports prioritization of care. They, however, focused on semi-elective surgeries, including cardiothoracic, oncological and transplantation surgery, whereas we

focused on elective surgeries. Needless to say that cancer patients and patients awaiting organ transplantation have a completely different profile as far as prognosis of their disease on the one hand and burden of awaiting treatment, on the other, is concerned. Furthermore, they used the global burden of disease by the WHO to estimate the QALY for 1/3 of the surgeries, and for the other 2/3 they used estimates by an expert panel. Our quality of life data are based on literature data from comparative studies using validated quality of life measures, which is in agreement with the ISPOR recommendation to use health-utility data collected from patients.[54] Wang et al.[55] developed a framework to model surgical backlog recovery. In contrast to our model, they did not include quality of life assessment to guide prioritization of care. They used available resources and bed capacity that are adjustable to other contexts, aiding region-specific decision-making. The COVIDSurg Collaborative[2] and Brandman et al.[56] separately developed models to predict the size of the backlog and time needed to restore this backlog. Although these models are different from the present framework, combining both perspectives might result in a comprehensive context specific policy to clear the surgical backlog.

The major strength of our approach is that the data used from literature are completely transparent in the online framework, and that it can easily be adapted according to local settings (e.g. regarding operation times) and new available evidence. Our model was built with high-quality QoL- and cost data that were derived from randomised controlled trials or comparative studies. We had the unique opportunity to cross validate our results to a national study by the Dutch Institute for Public Health and the Environment and empirical data from a large local hospital.[7] The concordance appeared to be very high with more than 75% overlap. Furthermore, by calculating the net monetary losses per week weighed by OR minute we were able to make a comparison between procedures and surgical disciplines based on the surgery time. This provides new insights on how to allocate valuable surgery time when comparing these operations, to maximize value.

Some potential limitations should also be discussed. First, we used average data from literature rather than patient-level data, which could impact the applicability of our results to the individual patient. However, our goal was to develop a practical framework to support priority setting able to generalize and compare on department and surgery level instead. The model is therefore useful in general during the COVID-19 pandemic as well as for policy-making in striving for quality-driven healthcare.

Second, we did not yet take into account other related factors such as ICU or personnel capacity, the number of beds available, the risk of exposing patients to perioperative COVID-19 infection, or psychological consequences. This was outside the scope of this paper but can be added in a future model, and of course these factors can be taken into account in the individual trade-off.

Third, impact of waiting on medication costs (for example pain medication that patients need while waiting for surgery), could not be taken into account because they were either not reported in literature or not described in enough detail to be suitable for inclusion in the model. In order to be able to take medication costs into account, better reporting of cost data, i.e. categorization of cost data, in clinical studies is needed. Furthermore, it could be expected that some patients need extra home care or had a prolonged stay in a nursing home because they are waiting for surgery. These costs were not reported in literature and were therefore not included in the model. Consequently, the total cost presented are an underestimation of the real cost.

Fourth, besides impact on quality of life, delayed surgery may have a variety of consequences regarding the deterioration of the disease ranging from 'no harm' (varices, inguinal hernia) to 'complications' (easy or difficult to treat, medically or surgically: Crohn's disease, ulcerative colitis) to disease-related death. Currently, high-quality data regarding the consequences of the delay of surgery on deterioration are lacking and could therefore not be included in our model. Because of the elective nature of the included procedures, we believe that deterioration with high impact (like disease-related death) will be limited. However, if this COVID-19 pandemic will prove that delaying

the included procedures do lead to high impact deterioration it is necessary to include the consequences of delaying surgery, the model can be adapted accordingly.

Fifth, so far, we only modelled 13 elective surgical procedures whereas there are many more. Since we developed an online framework, new data can easily be added to inform future decision making, for example additional high quality data comparing surgery to watchful waiting or non-surgical care. Others can also provide us with relevant information on other procedures, which we will check on consistency and validity, before adding them to the online framework.

Sixth, for some procedures no data on quality of life or costs were available in literature. The fact that no relevant data were retrieved from literature for sphincteroplasty , male sling procedure, and tension-free vaginal tape procedure illustrates how difficult it is, and will be, to calculate the added value of these procedures. It renders this type of surgery ‘vulnerable’ in strategic discussions, but also stimulates groups active in this complex field to come up with data in support of continuing this type of operations. We are, however, aware of research projects that will follow the patients currently ‘waiting’ due to the backlog of the pandemic.[57] Hopefully, these projects will provide us with more accurate data, which are critical to obtain reliable estimates.

The ongoing pandemic is having a collateral damage effect on health care and the delivery of surgical care to millions of patients worldwide. This is an effect that most certainly will persist for years to come. It is to be expected that cancer and other acute surgery, if cancelled during the pandemic, will be prioritized in most settings, whereas the impact on other elective surgeries for benign conditions will be cumulative, adding to the existing waiting times. Governments and other policy makers will be requested to fund substantial increases in surgical volume to clear backlogs, and this framework may help them to prioritize on evidence regarding QoL and cost savings rather than on a mixture of numbers and expert opinion.

When addressing the backlog of postponed elective surgeries, it is tempting to start with surgeries that cause a high net monetary loss when delayed on the one hand and have large volumes on the

other. However, as we look at bariatric surgery, we see a discrepancy between population impact and net monetary loss per OR minute. Although bariatric surgery has one of the highest net monetary losses of all procedures described in this paper, it has the lowest impact on population level due to small volumes. Also, when resuming total knee and total hip replacement first, huge numbers of patients need to be operated taking a lot of valuable OR time, while for bariatric surgery only a small number of patients needs to be operated. Therefore, we would like to emphasize that objective measures are indispensable for fair and justifiable prioritization of surgeries, and that these choices are preferably based on the net monetary loss per OR minute. Such medical care prioritisation data may add to future discussions on “appropriate use” of health care budgets.

In conclusion, our online framework can be used in deciding how to address the postponed elective surgeries after the COVID-19 pandemic. Furthermore, the model will also be useful during possible future repeated waves of COVID-19 or in the long-term as it provides relevant information regarding an efficient distribution of OR time.

Declarations

Competing interests

MR had financial support by means of a VICI grant from NWO (Dutch Research Council) for the submitted work, the other authors had no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work

Licence

The Corresponding Author has the right to grant on behalf of all authors and does grant on behalf of all authors, an exclusive licence (or non exclusive for government employees) on a worldwide basis to the BMJ Publishing Group Ltd ("BMJ"), and its Licencees to permit this article (if accepted) to be published in The BMJ's editions and any other BMJ products and to exploit all subsidiary rights, as set out in our licence.

Contributors and sources

MR, SW, JG, HG, MS and TG have contributed to the conception and design of the study. All authors have contributed to the final design of the paper. Modelling was performed by SW, SM, RV, MS, TG, CM, MJ, IS and NvdB. Model input and feedback was received from RvdP, BB, HG, CT, MS, CR, SvdG, TvT, RP, JR and NS. MR, SW, MS and TG drafted the manuscript. The online framework as developed by SW. All authors have made contributions to the drafting and revising of the article. All authors have read, reviewed and approved the final version of the manuscript before submission.

Role of the funding source

The study was funded by NWO (Dutch Research Council), VICI-project Rovers, project number 91818617. The funder had no role in the study design; in the collection, analysis, and interpretation of data; in the writing of the report; and in the decision to submit the article for publication. All authors were independent from the funder. All authors had full access to all of the data and can take responsibility for the integrity of the data and the accuracy of the data analysis. There was no commercial involvement in the study.

Patient and public involvement

It was not possible to involve patients or the public in the design, conduct, or reporting of our research. Dissemination to participants and related patient and public communities: The framework is available online at: https://stanwijn.shinyapps.io/priORitize/),

Transparancy

The lead authors affirm that the manuscript is an honest, accurate, and transparent account of the study being reported; and that no important aspects of the study have been omitted.

Data sharing

Detailed extracted data on all included elective surgical procedures are available in the online framework.

References

1. Søreide K, Hallet J, Matthews JB, Schnitzbauer AA, Line PD, Lai PBS, et al. Immediate and long-term impact of the COVID-19 pandemic on delivery of surgical services. Br. J. Surg. John Wiley and Sons Ltd; 2020. p. 1250–61.
2. Nepogodiev D, Omar OM, Glasbey JC, Li E, Simoes JFF, Abbott TEF, et al. Elective surgery cancellations due to the COVID-19 pandemic: global predictive modelling to inform surgical recovery plans. Br. J. Surg. 2020;107(11):1440–9.
3. Fowler AJ, Dobbs TD, Wan YI, Laloo R, Hui S, Nepogodiev D, et al. Resource requirements for reintroducing elective surgery during the COVID-19 pandemic: modelling study. Br. J. Surg. 2021;108(1):97–103.
4. Brody H. Medicine's Ethical Responsibility for Health Care Reform — The Top Five List. N. Engl. J. Med. 2010;362(4):283–5.
5. Morden NE, Colla CH, Sequist TD, Rosenthal MB. Choosing Wisely — The Politics and Economics of Labeling Low-Value Services. N. Engl. J. Med. 2014;370(7):589–92.
6. Dutch Healthcare Authority (NZa). Urgentielijst medisch-specialistische zorg - Nederlandse Zorgautoriteit [Internet]. [cited 2021 Mar 18]. Available from: https://puc.overheid.nl/nza/doc/PUC_306624_22/1/
7. Giessen A van, Wit A de, Brink C van den, Degeling K, Deuning C, Eeuwijk J, et al. Impact of the first wave of COVID-19 on regular healthcare and health [Internet]. 2020 [cited 2021 Mar 18]. p. 158. Available from: https://www.rivm.nl/en/bibcite/reference/337271
8. Rabin R, De Charro F. EQ-5D: A measure of health status from the EuroQol Group. In: Annals of Medicine. Royal Society of Medicine Press Ltd; 2001. p. 337–43.
9. Versteegh M, M. Vermeulen K, M. A. A. Evers S, de Wit GA, Prenger R, A. Stolk E. Dutch Tariff for the Five-Level Version of EQ-5D. Value Heal. 2016;19(4):343–52.
10. Hakkaart-van Roijen L, van der Linden N, Bouwmans C, Kanters T, Swan Tan S. Kostenhandleiding: Methodologie van kostenonderzoek en referentieprijzen voor

economische evaluaties in de gezondheidszorg [Internet]. Dutch Natl. Heal. Care Inst. 2016. p. 1–73. Available from: https://www.zorginstituutnederland.nl/over-ons/publicaties/publicatie/2016/02/29/richtlijn-voor-het-uitvoeren-van-economische-evaluaties-in-de-gezondheidszorg

11. Chang W, Cheng J, Allaire JJ, Xie Y MJ. shiny: Web Application Framework for R version 1.3.2 from CRAN [Internet]. Compr. R Arch. Netw. 2017 [cited 2021 Mar 26]. Available from: https://rdrr.io/cran/shiny/

12. Chang W, Ribeiro BB. Package “ShinyDashboard”: Create Dashboards with “Shiny” [Internet]. Comprehensive R Archive Network (CRAN); 2018 [cited 2021 Mar 26]. p. 27. Available from: https://cran.r-project.org/package=shinydashboard

13. Langeveld HR, van’t Riet M, Weidema WF, Stassen LPS, Steyerberg EW, Lange J, et al. Total Extraperitoneal Inguinal Hernia Repair Compared With Lichtenstein (the LEVEL-Trial). Ann. Surg. 2010;251(5):819–24.

14. Chard J, Kuczawski M, Black N, van der Meulen J. Outcomes of elective surgery undertaken in independent sector treatment centres and NHS providers in England: audit of patient outcomes in surgery. BMJ. 2011;343(oct19 1):d6404–d6404.

15. Fitzgibbons RJ, Giobbie-Hurder A, Gibbs JO, Dunlop DD, Reda DJ, McCarthy M, et al. Watchful Waiting vs Repair of Inguinal Hernia in Minimally Symptomatic Men. JAMA. 2006;295(3):285.

16. Stroupe KT, Manheim LM, Luo P, Giobbie-Hurder A, Hynes DM, Jonasson O, et al. Tension-Free Repair Versus Watchful Waiting for Men with Asymptomatic or Minimally Symptomatic Inguinal Hernias: A Cost-Effectiveness Analysis. J. Am. Coll. Surg. 2006;203(4):458–68.

17. Poelemeijer YQM, Liem RSL, Nienhuijs SW. A Dutch Nationwide Bariatric Quality Registry: DATO. Obes. Surg. 2018;28(6):1602–10.

18. Dogan K, Kraaij L, Aarts EO, Koehestanie P, Hammink E, van Laarhoven CJHM, et al. Fast-Track Bariatric Surgery Improves Perioperative Care and Logistics Compared to Conventional Care. Obes. Surg. 2015;25(1):28–35.

19. Sendi P, Brunotte R, Potoczna N, Branson R, Horber FF. Health-Related Quality of Life in Patients with Class II and Class III Obesity. Obes. Surg. 2005;15(7):1070–6.

20. Biter LU, van Buuren MMA, Mannaerts GHH, Apers JA, Dunkelgrün M, Vijgen GHEJ. Quality of Life 1 Year After Laparoscopic Sleeve Gastrectomy Versus Laparoscopic Roux-en-Y Gastric Bypass: a Randomized Controlled Trial Focusing on Gastroesophageal Reflux Disease. Obes. Surg. 2017;27(10):2557–65.

21. Espallardo O, Busutil R, Torres A, Zozaya N, Villoro R, Hidalgo-Vega Á. The Impact of Severe Obesity on Healthcare Resource Utilisation in Spain. Obes. Surg. 2017;27(8):2058–66.

22. Backes CF, Lopes E, Tetelbom A, Heineck I. Medication and nutritional supplement use before and after bariatric surgery. Sao Paulo Med. J. 2016;134(6):491–500.

23. Khan SS, Ning H, Wilkins JT, Allen N, Carnethon M, Berry JD, et al. Association of Body Mass Index With Lifetime Risk of Cardiovascular Disease and Compression of Morbidity. JAMA Cardiol. 2018;3(4):280.

24. Segal JB, Clark JM, Shore AD, Dominici F, Magnuson T, Richards TM, et al. Prompt Reduction in Use of Medications for Comorbid Conditions After Bariatric Surgery. Obes. Surg. 2009;19(12):1646–56.

25. Stark RG, Reitmeir P, Leidl R, König H-H. Validity, reliability, and responsiveness of the EQ-5D in inflammatory bowel disease in Germany. Inflamm. Bowel Dis. 2010;16(1):42–51.

26. Harrison OJ, Smart NJ, White P, Brigic A, Carlisle ER, Allison AS, et al. Operative Time and Outcome of Enhanced Recovery After Surgery After Laparoscopic Colorectal Surgery. JSLS J. Soc. Laparoendosc. Surg. 2014;18(2):265–72.

27. Huppertz-Hauss G, Høivik ML, Langholz E, Odes S, Småstuen M, Stockbrugger R, et al. Health-related Quality of Life in Inflammatory Bowel Disease in a European-wide Population-based Cohort 10 Years After Diagnosis. Inflamm. Bowel Dis. 2015;21(2):337–44.

28. Penner RM, Tandon P. Management of Crohn disease after surgical resection - UpToDate [Internet]. Up To Date. 2017 [cited 2021 Apr 8]. Available from:

https://www.uptodate.com/contents/management-of-crohn-disease-after-surgical-resection?search=crohn disease surgical treatment&topicRef=86198&source=see_link%0Ahttps://www.uptodate.com/contents/management-of-crohn-disease-after-surgical-resection?source=h

29. Rubin GP, Hungin APS, Kelly PJ, Ling J. Inflammatory bowel disease: epidemiology and management in an English general practice population. Aliment. Pharmacol. Ther. 2000;14(12):1553–9.

30. Miehsler W, Weichselberger M, Öfferlbauer-Ernst A, Dejaco C, Reinisch W, Vogelsang H, et al. Which patients with IBD need psychological interventions? A controlled study. Inflamm. Bowel Dis. 2008;14(9):1273–80.

31. Thia KT, Sandborn WJ, Harmsen WS, Zinsmeister AR, Loftus E V. Risk Factors Associated With Progression to Intestinal Complications of Crohn's Disease in a Population-Based Cohort. Gastroenterology. 2010;139(4):1147–55.

32. Hsu Y-C, Wu T-C, Lo Y-C, Wang L-S. Gastrointestinal complications and extraintestinal manifestations of inflammatory bowel disease in Taiwan: A population-based study. J. Chinese Med. Assoc. 2017;80(2):56–62.

33. Ratto C, Litta F, Donisi L, Parello A. Fistulotomy or fistulectomy and primary sphincteroplasty for anal fistula (FIPS): a systematic review. Tech. Coloproctol. 2015;19(7):391–400.

34. Johnson EC, Horwood J, Gooberman-Hill R. Conceptualising time before surgery: The experience of patients waiting for hip replacement. Soc. Sci. Med. 2014;116:126–33.

35. Konopka JF, Lee Y, Su EP, McLawhorn AS. Quality-Adjusted Life Years After Hip and Knee Arthroplasty. JBJS Open Access. 2018;3(3):e0007.

36. Fordham R, Skinner J, Wang X, Nolan J. The economic benefit of hip replacement: a 5-year follow-up of costs and outcomes in the Exeter Primary Outcomes Study. BMJ Open. 2012;2(3):e000752.

37. Rolfson O, Dahlberg LE, Nilsson J-å., Malchau H, Garellick G. Variables determining outcome in

total hip replacement surgery. J. Bone Joint Surg. Br. 2009;91-B(2):157–61.

38. Bozic KJ, Stacey B, Berger A, Sadosky A, Oster G. Resource utilization and costs before and after total joint arthroplasty. BMC Health Serv. Res. 2012;12(1):73.

39. Gordon M, Greene M, Frumento P, Rolfson O, Garellick G, Stark A. Age- and health-related quality of life after total hip replacement. Acta Orthop. 2014;85(3):244–9.

40. Ravi B, Jenkinson R, O'Heireamhoin S, Austin PC, Aktar S, Leroux TS, et al. Surgical duration is associated with an increased risk of periprosthetic infection following total knee arthroplasty: A population-based retrospective cohort study. EClinicalMedicine. 2019;16:74–80.

41. Picard F, Deakin A, Balasubramanian N, Gregori A. Minimally invasive total knee replacement: techniques and results. Eur. J. Orthop. Surg. Traumatol. 2018;28(5):781–91.

42. Jansson K-Å, Granath F. Health-related quality of life (EQ-5D) before and after orthopedic surgery. Acta Orthop. 2011;82(1):82–9.

43. Grobet CE, Glanzmann MC, Eichler K, Rickenbacher D, Meier F, Brunner B, et al. Cost-utility analysis of total shoulder arthroplasty: A prospective health economic study using real-world data. J. Shoulder Elb. Surg. 2021;1.

44. Evans J, Dattani R, Ramasamy V, Patel V. Responsiveness of the EQ-5D-3L in elective shoulder surgery: Does it adequately represent patient experience? J. Orthop. Surg. 2018;26(2).

45. Dunn JC, Lanzi J, Kusnezov N, Bader J, Waterman BR, Belmont PJ. Predictors of length of stay after elective total shoulder arthroplasty in the United States. J. Shoulder Elb. Surg. 2015;24(5):754–9.

46. Padegimas EM, Hendy BA, Lawrence C, Devasagayaraj R, Zmistowski BM, Abboud JA, et al. An analysis of surgical and nonsurgical operating room times in high-volume shoulder arthroplasty. J. Shoulder Elb. Surg. 2017;26(6):1058–63.

47. Van De Graaf VA, Van Dongen JM, Willigenburg NW, Noorduyn JCA, Butter IK, De Gast A, et al. How do the costs of physical therapy and arthroscopic partial meniscectomy compare? A trial-based economic evaluation of two treatments in patients with meniscal tears alongside the

ESCAPE study. Br. J. Sports Med. 2020;54(9):538–46.

48. van Egmond MMHT, Rovers MM, Hannink G, Hendriks CTM, van Heerbeek N. Septoplasty with or without concurrent turbinate surgery versus non-surgical management for nasal obstruction in adults with a deviated septum: a pragmatic, randomised controlled trial. Lancet. 2019;394(10195):314–21.

49. Menezes AS, Guimarães JR, Breda M, Vieira V, Dias L. Septal and turbinate surgery: is overnight essential? Eur. Arch. Oto-Rhino-Laryngology. 2018;275(1):131–8.

50. Leruth J, Waltregny D, de Leval J. The Inside-Out Transobturator Male Sling for the Surgical Treatment of Stress Urinary Incontinence After Radical Prostatectomy: Midterm Results of a Single-Center Prospective Study. Eur. Urol. 2012;61(3):608–15.

51. Manca A, Sculpher MJ, Ward K, Hilton P. A cost-utility analysis of tension-free vaginal tape versus colposuspension for primary urodynamic stress incontinence. BJOG. 2003;110(3):255–62.

52. Degeling K, Baxter NN, Emery J, Jenkins MA, Franchini F, Gibbs P, et al. An inverse stage-shift model to estimate the excess mortality and health economic impact of delayed access to cancer services due to the COVID-19 pandemic. Asia. Pac. J. Clin. Oncol. 2021;ajco.13505.

53. Gravesteijn B, Krijkamp E, Busschbach J, Geleijnse G, Helmrich IR, Bruinsma S, et al. Minimizing Population Health Loss in Times of Scarce Surgical Capacity During the Coronavirus Disease 2019 Crisis and Beyond: A Modeling Study. Value Heal. 2021;1–10.

54. Brazier J, Ara R, Azzabi I, Busschbach J, Chevrou-Séverac H, Crawford B, et al. Identification, Review, and Use of Health State Utilities in Cost-Effectiveness Models: An ISPOR Good Practices for Outcomes Research Task Force Report. Value Heal. 2019;22(3):267–75.

55. Wang J, Vahid S, Eberg M, Milroy S, Milkovich J, Wright FC, et al. Clearing the surgical backlog caused by COVID-19 in Ontario: A time series modelling study. CMAJ. 2020;192(44):E1347–56.

56. Brandman DM, Leck E, Christie S. Modelling the backlog of COVID-19 cases for a surgical group. Can. J. Surg. 2020;63(5):E391–2.

57. TRACE II: Patiëntuitkomsten na uitgestelde electieve operaties tijdens de COVID-19 pandemie - ZonMw [Internet]. [cited 2021 Mar 18]. Available from: https://www.zonmw.nl/nl/over-zonmw/coronavirus/programmas/project-detail/covid-19-programma/trace-ii-outcome-in-patients-undergoing-postponed-elective-surgery-during-the-covid-19-pandemic/

Table 1. The 13 surgical procedures that are currently included in the framework.

Surgical procedure	Surgical specialty	Indication for surgery
Inguinal hernia repair	General surgery	Inguinal hernia
Laparoscopic sleeve gastrectomy	General surgery	Morbid obesity
laparoscopic Roux-and-Y gastric bypass	General surgery	Morbid obesity
Partial colectomy	Gastrointestinal surgery	Symptomatic Crohn's disease
Partial colectomy	Gastrointestinal surgery	Ulcerative colitis
Sphincteroplasty	Gastrointestinal surgery	Faecal incontinence
Total hip replacement	Orthopaedic surgery	Osteoarthritis of the hip
Total knee replacement	Orthopaedic surgery	Osteoarthritis of the knee
Total shoulder replacement	Orthopaedic surgery	Osteoarthritis of the shoulder
Arthroscopic partial meniscectomy	Orthopaedic surgery	Degenerative lesion of the meniscus
Septoplasty	Otorhinolaryngology	Nasal obstruction and/or deviated septum
Male sling procedure	Urology	Moderate stress urinary incontinence in men
Tension-free vaginal tape procedure	Urology	Stress urinary incontinence in women

Table 2. Overview of the data in the surgical prioritization framework.

Surgical procedure	Surgical specialty	Operating time (min)	Utility pre-surgery	Utility post-surgery	Δ Utility	Cost per week (€)	NML per week (€)	NML by operating time (€)	References
Inguinal hernia repair	General surgery	54	0.78	0.88	0.1	€ 0	-€ 38	-€ 0.7	[13–16]
Laparoscopic sleeve gastrectomy	General surgery	71	0.73	0.87	0.14	€ 31	-€ 85	-€ 1.2	[17–24]
laparoscopic Roux-and-Y gastric bypass	General surgery	82	0.75	0.87	0.12	€ 31	-€ 77	-€ 0.9	[17–24]
Partial colectomy – Non-acute Crohn's disease	Gastrointestinal surgery	180	0.75	0.95	0.2	€ 17	-€ 94	-€ 0.5	[25–32]
Partial colectomy – Ulcerative colitis	Gastrointestinal surgery	180	0.84	0.96	0.12	€ 16	-€ 62	-€ 0.3	[25–32]
Sphincteroplasty	Gastrointestinal surgery	180	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	[33]
Total hip replacement	Orthopaedic surgery	150	0.52	0.79	0.27	€ 10	-€ 114	-€ 0.8	[34–39]
Total knee replacement	Orthopaedic surgery	106	0.51	0.73	0.22	€ 10	-€ 95	-€ 0.9	[38,40–42]
Total shoulder replacement	Orthopaedic surgery	181	0.66	0.89	0.22	n.a.	n.a.	n.a.	[43–46]

Arthroscopic partial meniscectomy	Orthopaedic surgery	50	0.75	0.8	0.05	-€ 2	-€ 18	-€ 0.3	[47]
Septoplasty	Otorhinolaryngology	61	0.83	0.89	0.06	-€ 1	-€ 22	-€ 0.4	[48,49]
Male sling procedure	Urology	59	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	[50]
Tension-free vaginal tape procedure	Urology	56	0.78	n.a.	n.a.	n.a.	n.a.	n.a.	[51]

Min: minutes, n.a.: not available, NML: net monetary loss.

Figure 1: Loss in quality of life due to delayed surgery

<insert Figure 1>

Loss in quality of life (QoL) due to delayed or postponed surgery expressed as a utility score.

A utility reflects QoL on a 0 to 1 scale, with 0 representing death and 1 representing full health

Figure 2: Cost associated with waiting for surgery (per week)

<insert Figure 2>

Extra health care expenditure due to waiting for surgery

Figure 3: Surgery associated net monetary loss per week

<insert Figure 3>

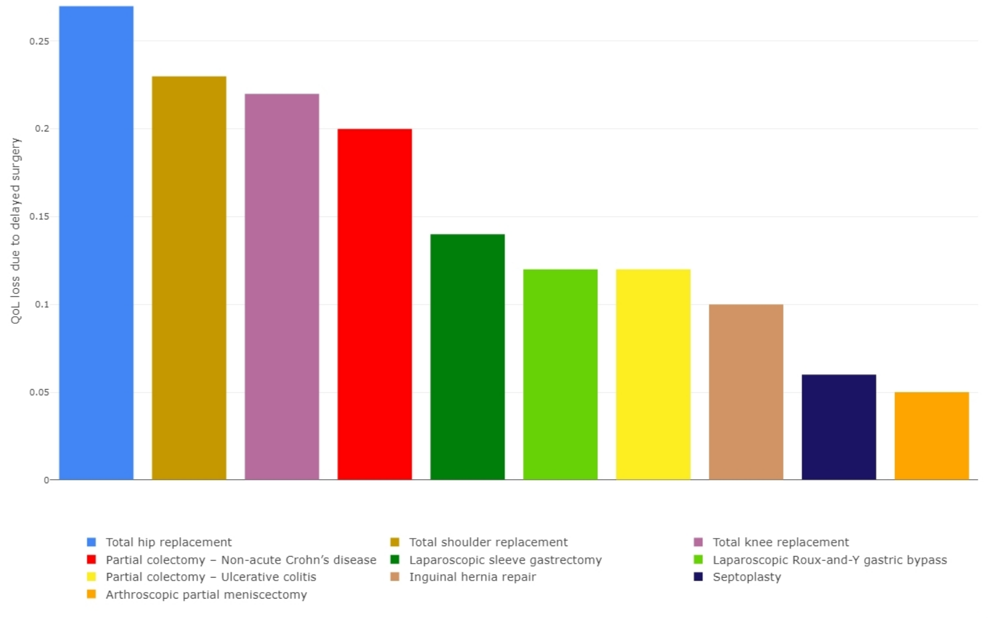
The net monetary loss combines QoL and costs due to waiting for surgery, it is therefore the

Figure 4: Surgery associated net monetary loss weighted by operating time

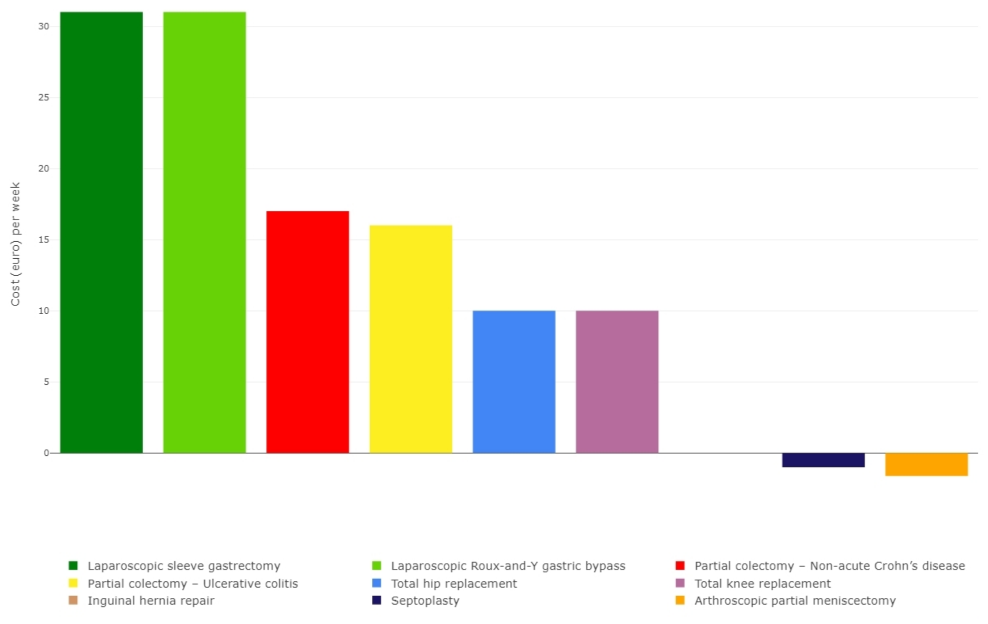
<insert Figure 4>

Surgery associated net monetary loss per week divided by operating time, i.e. it reflects the

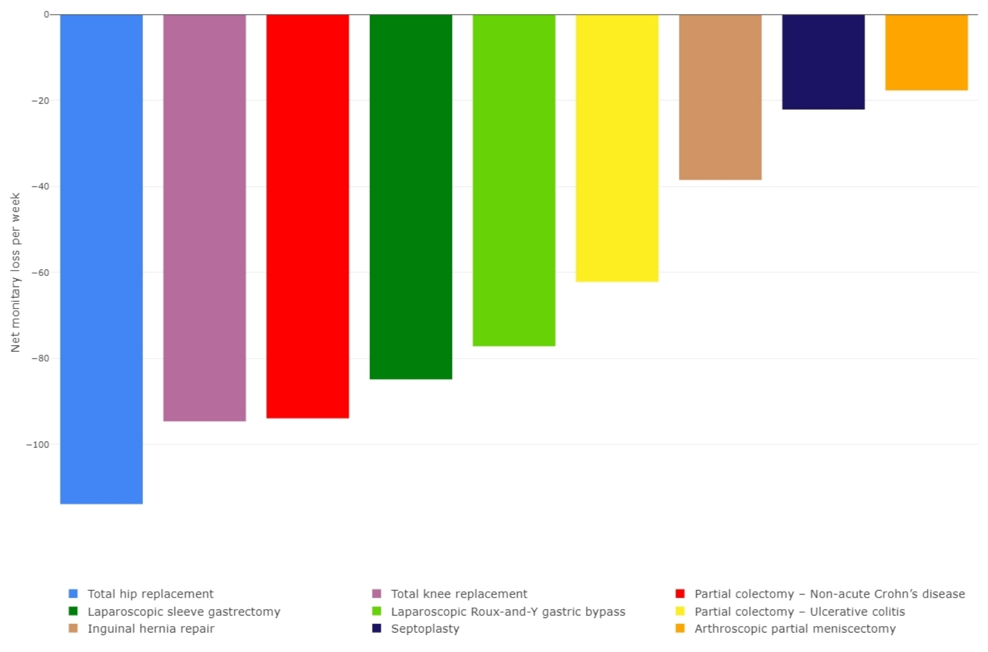
total loss of waiting another week for surgery, expressed in monetary terms	*total cost per week per OR minute.*



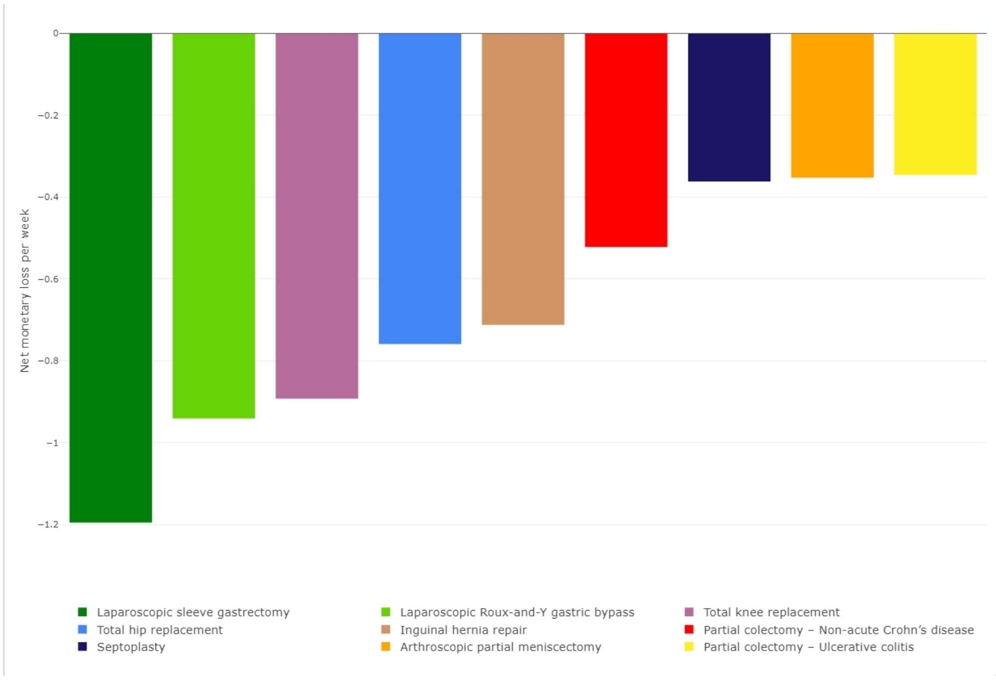
327x220mm (96 x 96 DPI)



327x220mm (96 x 96 DPI)



327x220mm (96 x 96 DPI)



327x220mm (96 x 96 DPI)

Supplement S1: Search strategy for model data

<u>OR Time / Length of stay after OR</u>

- Disease
- Surgery type
- Length of stay / hospital stay
- Optional: Netherlands, Europe, UK, Germany

Pubmed:

1. "<Disease>" AND "<Surgery type>" FILTER RCT
2. "<Disease>" AND "<Surgery type>" AND ("length of stay" OR "hospital stay")
3. Patient information folder

<u>Utility scores</u>

- Utility score / EQ5D /Quality of Life
- Disease
- Surgery type
- Conservative treatment / conservative care / watchful waiting
- Optional: Netherlands, Europe, UK, Germany

Pubmed:

"Utility score" OR "EQ5D" OR "Quality of Life" AND

1. "<disease name>" OR "<surgery type>"
2. "Conservative treatment" OR "Conservative care" OR "Watchful waiting"

<u>Costing data</u>

- Costs / Resource use / Resources / Resource utilisation / Healthcare utilization
- Disease
- Surgery type
- Conservative treatment / conservative care/watchful waiting
- Optional: Netherlands, Europe, UK, Germany

Pubmed:

"Costs" OR "Resource use" OR "Resources" OR "Resource utilization" OR "Healthcare utilization" AND

1. "<disease name>" OR "<surgery type>"
2. "Conservative treatment" OR "Conservative care" OR "Watchful waiting"

Supplement S2. Impact of surgical delay for the Netherlands

Surgical procedure	Average number of surgeries per week	Costs associated with delay					Net monetary loss per week				
		% of surgeries delayed					% of surgeries delayed				
		10%	20%	30%	40%	50%	10%	20%	30%	40%	50%
Inguinal hernia repair	535.9	€0	€0	€0	€0	€0	€-2061	€-4122	€-6183	€-8244	€-10305
Laparoscopic sleeve gastrectomy	1.5	€5	€9	€14	€18	€23	€-13	€-25	€-38	€-51	€-63
laparoscopic Roux-and-Y gastric bypass	2.7	€8	€17	€25	€34	€42	€-21	€-42	€-63	€-84	€-105
Partial colectomy – Non-acute Crohn's disease	25.5	43	€86	€128	€171	€214	€-239	€-478	€-718	€-957	€-1196
Partial colectomy – Ulcerative colitis	9.8	€16	€31	€47	€62	€78	€-61	€-121	€-182	€-243	€-303
Sphincteroplasty	0.8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Total hip replacement	574.3	€553	€1106	€1660	€2213	€2766	€-6539	€-13078	€-19617	€-26156	€-32695
Total knee replacement	552.5	€532	€1065	€1597	€2129	€2661	€-5207	€-10415	€-15622	€-20830	€-26037
Total shoulder replacement	56.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Arthroscopic partial meniscectomy	406.8	€-65	€-131	€-196	€-262	€-327	€-731	€-1462	€-2193	€-2923	€-3654
Septoplasty	181.2	€-14	€-27	€-41	€-55	€-69	€-404	€-809	€-1213	€-1618	€-2022
Male sling procedure	2.6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tension-free vaginal tape procedure	66.5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Total per week*	2290	€1,077	€2,155	€3,232	€4,310	€5,388	-€15,764	-€31,529	-€47,293	-€63,058	-€78,823

*only including procedures with available cost and NML data
n.a. not available, NML: net monetary loss

Supplement S3. Waiting lists and net monetary losses of a large regional hospital in The Netherlands on 30 June 2020, 2019 and 2018.

Surgical procedure	2018				2019				2020			
	Patients waiting for surgery	Waiting time	Costs associated with delay	Net monetary loss	Patients waiting for surgery	Waiting time	Costs associated with delay	Net monetary loss	Patients waiting for surgery	Waiting time	Costs associated with delay	Net monetary loss
Inguinal hernia repair	25	4	€ 0	-€ 3,441	40	4	€ 0	-€ 6,851	36	12	€ 0	-€ 16,397
Laparoscopic sleeve gastrectomy	11	6	€ 1,943	-€ 5,316	3	5	€ 491	-€ 1,342	19	10	€ 5,682	-€ 15,543
laparoscopic Roux-and-Y gastric bypass	13	5	€ 2,046	-€ 5,095	7	6	€ 1,262	-€ 3,143	30	12	€ 10,798	-€ 26,890
Partial colectomy – Non-acute Crohn's disease	0	1	€ 0	€ 0	0	3	€ 0	€ 0	0	6	€ 0	€0
Partial colectomy – Ulcerative colitis	3	2	€ 100	-€ 387	1	2	€ 36	-€ 140	1	2	€ 34	-€ 131
Sphincteroplasty	0	3	n.a.	n.a.	1	6	n.a.	n.a.	1	0	n.a.	n.a.
Total hip replacement	57	7	€ 4,153	-€ 47,285	66	9	€ 6,016	-€ 68,489	202	17	€ 33,501	-€ 381,404
Total knee replacement	71	8	€ 5,836	-€ 55,216	71	11	€ 7,605	-€ 71,956	193	21	€ 39,770	-€ 376,299
Total shoulder replacement	4	6	n.a.	n.a.	3	8	n.a.	n.a.	11	14	n.a.	n.a.
Arthroscopic partial meniscectomy	17	4	-€ 112	-€ 1,227	19	5	-€ 139	-€ 1,527	15	13	-€ 317	-€ 3,475
Septoplasty	40	7	-€ 283	-€ 6,258	72	12	-€ 870	-€ 19,217	103	23	-€ 2,417	-€ 53,365
Male sling procedure	12	7	n.a.	n.a.	6	13	n.a.	n.a.	11	14	n.a.	n.a.
Tension-free vaginal tape procedure	4	14	n.a.	n.a.	2	32	n.a.	n.a.	2	17	n.a.	n.a.
Total	257		€ 13,682*	-€ 124,224*	291		€ 14,399*	-€ 172,664*	624		€ 87,049*	-€ 873,504*

* *only including procedures with available cost and NML data
n.a. not available, NML: net monetary loss

Lessons learned from delayed elective surgeries during the COVID-19 pandemic: development of a decision analytical framework to prioritize operating room capacity

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2021-054110.R1
Article Type:	Original research
Date Submitted by the Author:	11-Feb-2022
Complete List of Authors:	Rovers, Maroeska; Radboudumc, Operating Rooms and Health Evidence Wijn, Stan; Radboudumc, Operating Rooms Grutters, Janneke; Radboudumc, Health Evidence & Operating Rooms Metsemakers, Sanne; Radboudumc, Operating Rooms Vermeulen, Robin; Radboudumc, Operating Rooms Van der Pennen, Ron; Tweesteden Hospital Location Saint Elisabeth Berden, Bart; Elisabeth-TweeSteden Ziekenhuis Gooszen, Hein; Radboudumc, Operating Rooms - Evidence Based Surgery Scholte, Mirre; Radboudumc, Operating Rooms Govers, Tim; Radboudumc, Operating rooms
Primary Subject Heading:	Surgery
Secondary Subject Heading:	Health economics, Evidence based practice, Health policy
Keywords:	COVID-19, HEALTH ECONOMICS, Organisation of health services < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, SURGERY

SCHOLARONE™ Manuscripts

Lessons learned from delayed elective surgeries during the COVID-19 pandemic: development of a decision analytical framework to prioritize operating room capacity

Authors:

Maroeska M. Rovers[1,2], Stan R.W. Wijn[1], Janneke P. Grutters[1,2], Sanne Metsemakers[1], Robin Vermeulen[1], Ron van der Pennen[3], Bart Berden[3,4], Hein G. Gooszen[1], Mirre Scholte[1], Tim M. Govers[1]

Collaborators/acknowledgements:

Charlotte Michels[5,6], Milica Jevdjevic[7], Ilse Spenkelink[8], Niels van den Berkmortel[2], Casper Tax[9], Michiel Sedelaar[10], Camiel Rosman[11], Sebastiaan van der Goes[12], Tony van Tienen[13], Rudolph Poolman[14], Jelle Ruurda[15], Niek Stadhouder[16], Paul van Leest[3].

1. Department of Operating Rooms, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.
2. Department for Health Evidence, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.
3. Elisabeth Tweesteden Hospital, Tilburg, The Netherlands.
4. IQ healthcare, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands
5. Department of Urology, Rijnstate Hospital, Arnhem, The Netherlands.
6. Department of Operating Rooms, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.
7. Department of Dentistry-Quality and Safety of Oral Healthcare, Radboud University Medical Center, Radboud Institute for Health Sciences, Nijmegen, The Netherlands

8. Department of Radiology, Nuclear Medicine and Anatomy, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.
9. Department of General Surgery, Haaglanden Medical Centre, The Hague, The Netherlands.
10. Department of Urology, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.
11. Department of Surgery, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.
12. Department of Orthopedics, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.
13. Orthopedic surgeon, Laurentius hospital Roermond
14. Department orthopedics, LUMC and OLVG, The Netherlands
15. Department of Surgery, University Medical Center Utrecht, The Netherlands
16. National Institute for Public Health and the Environment, PO Box 1, 3720 BA, Bilthoven, Netherlands

Correspondence to: M M Rovers, Radboud university medical center, Department of Operatng Rooms, route 715, PO Box 9101, 6500 HB Nijmegen, the Netherlands

E: Maroeska.Rovers@radboudumc.nl, T: +31-622726370

Abstract

Objective: To develop a prioritization framework to support priority setting for elective surgeries after COVID-19 based on the impact on patient well-being and cost.

Design: We developed decision analytic models to estimate the consequences of delayed elective surgical procedures (e.g. total hip replacement, bariatric surgery or septoplasty)

Setting: The framework was applied to a large hospital in the Netherlands.

Outcome measures: impacts on quality of life and costs were taken into accound and combined to calculate net monetary losses per week delay, which quantifies the total loss for society expressed in monetary terms. Net monetary losses were weighted by operating times.

Results: We studied 13 common elective procedures from four specialities. Highest loss in quality of life due to delayed surgery was found for total hip replacement (utility loss of 0.27, i.e. 99 days lost in perfect health); the lowest for arthroscopic partial meniscectomy (utility loss of 0.05, i.e. 18 days lost in perfect health). Costs of surgical delay per patient were highest for bariatric surgery (€31/pp per week) and lowest for arthroscopic partial meniscectomy (-€2/pp per week). Weighted by OR time bariatric surgery provides most value (€1.19/pp per OR minute), arthroscopic partial meniscectomy provides the least value (€0.34/pp per OR minute). In a large hospital the net monetary loss due to prolonged waiting times was €700.840 after the first COVID-19 wave, an increase of 506% compared to the year before.

Conclusions: This surgical prioritization framework can be tailored to specific centres and countries to support priority setting for delayed elective operations during and after the COVID-19 pandemic, both in and between surgical disciplines. In the long-term, the framework can contribute to the efficient distribution of OR time and will therefore add to the discussion on appropriate use of health care budgets. The online framework can be accessed via: https://stanwijn.shinyapps.io/priORitize/

Strengths and limitations of this study

- Decision analytical modelling appears to be an efficient tool to compare the impact of delays in elective surgery due to the COVID-19 pandemic on patient quality of life and healthcare costs.
- The framework is available via an online tool that can easily be adapted according to local settings (e.g. regarding operation times, currencies) and new available evidence.
- Since high-quality data regarding the consequences of the delay of surgery on deterioration are lacking, this could not be included in our model.
- We used average data from literature rather than patient-level data, which could impact the applicability of our results to the individual patient.

Keywords

COVID-19, cancelled elective surgeries, OR capacity, OR prioritization, quality of life, cost, online framework

Word count abstract: 300

Word count main text (Background through Conclusions): 4194

Introduction

The extent to which the ongoing COVID-19 pandemic is disrupting global health, social welfare and the economy is unparalleled in modern history.[1] Due to this pandemic, hospitals, continue to have to drastically reduce elective surgeries. Current estimates suggest that worldwide more than 2 million operations per week have been cancelled during the first wave of this pandemic, and most of them comprise elective surgeries.[2,3] In the UK alone a reduction of 2.3 million performed elective surgerie is seen from march 2020 untill February 2022, increasing the number of patients waiting for elective surgery to 6 million.[4,5] It was also estimated that if countries increase their usual surgical volume by 20 percent after the pandemic, it would take about 45 weeks to clear the backlog due to the disruption.[2] With the current second wave and third waves, the number of delayed elective operations will only increase further. This not only affects the surgical disciplines, but also other related disciplines like gastroenterology, internal medicine, oncology, cardiology, neurology and general practitioners as they see the rise in time for referral of patients for surgery.

The word "elective" implies that the indication for surgery is not 'acute and life-saving' like in the case of life-threatening emergency. In most hospitals 'acute' cases have been scheduled without restriction during the pandemic. For the elective cases, it is likely that their suboptimal health status persisted during the extended waiting period, but there might also be patients where the delay to surgery may lead to deterioration of the disease and limit treatment options. However, it is also conceivable that their symptoms decrease during their extended waiting period, without affecting their personal life much, ultimately leading to cancelling of surgery.

The COVID-19 pandemic provides a unique opportunity to study these effects of delay of elective surgeries. Moreover, the discussion on healthcare interventions where scientific support for addition of value is limited or even lacking, has also been reopened. That is, healthcare professionals also have a responsibility to contribute to the affordability and accessibility of the healthcare system as a whole.[6,7] If healthcare can be made more sensible and qualitatively better, we can deliver more health care for less money. This requires not only a new mindset, but also reliable models and data to quantify the consequences of delay or even cancellation of surgery on patients and society. Models like ours will help to build an evidence-based framework which can be used to support priority setting for elective surgeries and subsequent optimisation of OR capacity. Therefore, our aim was to develop a framework to support priority setting for elective surgeries based on the impact on patient well-being and cost.

Methods

Decision analytic models were developed to estimate the consequences of delaying multiple elective surgical procedures, taking into account health impact and cost. The final framework, including all individual models, provides information on relevant factors that should be taken into account when prioritizing operations, i.e. loss in health-related quality of life (HRQoL), healthcare costs due to delay and the duration of the operation. We used data from available literature to calculate expected health loss and costs due to delay of surgery. The decision analytical models were developed in accordance with the modelling good research practices and described according to the CHEERS guidelines (Supplement S1).[8] Ethical approval was not required for this study as all data was obtained via literature searches.

Selected elective procedures

All procedures that could wait for at least 2 months after diagnosis according to the urgency categories of the Dutch Healthcare Authority during the early phase of the COVID-19 pandemic were considered for our model.[9] Clinical experts from multiple specialties were consulted to determine useful examples of clinical dilemmas in times of COVID-19. We decided to compare procedures within and between specialties to demonstrate how to prioritize within and between disciplines. The following elective procedures were included: general and gastrointestinal surgical procedures (inguinal hernia repair, laparoscopic sleeve gastrectomy (LSG), Roux-en-Y laparoscopic gastric bypass (LRYGB), partial colectomy for non-acute Crohn's disease & ulcerative colitis, sphincteroplasty), urological/gynaecological procedures (male sling procedure, tension free vaginal tape procedure), orthopaedic procedures (total hip replacement, total knee replacement, total shoulder replacement, arthroscopic partial meniscectomy), and one otorhinolaryngological procedure (septoplasty) (Table 1).

Table 1. The 13 surgical procedures that are currently included in the framework.

Surgical procedure	Surgical specialty	Indication for surgery
Inguinal hernia repair	General surgery	Inguinal hernia
Laparoscopic sleeve gastrectomy	General surgery	Morbid obesity
laparoscopic Roux-and-Y gastric bypass	General surgery	Morbid obesity
Partial colectomy	Gastrointestinal surgery	Symptomatic Crohn's disease
Partial colectomy	Gastrointestinal surgery	Ulcerative colitis
Sphincteroplasty	Gastrointestinal surgery	Faecal incontinence
Total hip replacement	Orthopaedic surgery	Osteoarthritis of the hip
Total knee replacement	Orthopaedic surgery	Osteoarthritis of the knee
Total shoulder replacement	Orthopaedic surgery	Osteoarthritis of the shoulder
Arthroscopic partial meniscectomy	Orthopaedic surgery	Degenerative lesion of the meniscus
Septoplasty	Otorhinolaryngology	Nasal obstruction and/or deviated septum
Male sling procedure	Urology	Moderate stress urinary incontinence in men
Tension-free vaginal tape procedure	Urology	Stress urinary incontinence in women

Data acquisition and validation

For each case, input regarding cost and quality of life was derived from recent literature via semi-systematic literature searches in PubMed. Keywords included the disease of interest, the type of surgery, length of stay, costs (resource use / healthcare utilization) and quality of life. The search strategy can be found in Supplement S2. Ideally, a randomized controlled trial (RCT) or meta-analysis of multiple RCT's comparing surgery to watchful waiting or non-surgical care, was used to inform the model. If these were not available, alternative high-quality data sources, such as observational cohort studies or equivalent alternatives, were retrieved. If studies comparing surgery to watchful waiting or non-surgical care were not available, before and after surgical studies were used to estimate the effect of postponing surgery. The quality of the studies was assessed using a checklist in which we scored the validity of the operation times and utilities used. In addition, for each case study a clinical expert was consulted to ensure that all important aspects of the patient population, disease and surgery were captured. To validate our data, we also compared them with data from the Dutch National Institute for Public Health and the Environment (RIVM) that studied the consequences of delayed surgery for the Dutch government.[10]

Quality of life

Effectiveness was measured in terms of utility values, which reflects health-related quality of life on a 0-1 scale, with 0 representing death and 1 representing full health. Utility values were derived from the EQ-5D questionnaire.[11,12] When available, differences in utilities between surgery and watchful waiting were extracted at 6-12 months intervals to calculate the gain in utility which can be reached by performing the surgery. If a watchful waiting cohort was not available, the baseline utility (measured before surgery) of surgical patients was taken to calculate the gain in utility which can be reached by performing the surgery.

We assumed that gain in utility that can be reached by performing a surgery represents the loss in utility in case surgery is delayed. That is, if an operation that increases a patients utility with 0.2 is postponed for one year, we assume a total loss of utility of 0.2 over that year. Figure 1a shows how we calculated the impact of delayed surgery on the loss of quality of life (in utility values).

[*insert Figure 1*]

Costs

The extra health care expenditure due to waiting for surgery was determined by calculating the difference in healthcare expenditure before and after surgery (Figure 1b). Only costs from a healthcare perspective were included, e.g. extra visits to the hospital, general practitioner, physiotherapist. Costs of surgery itself were not included, as we assumed that all patients would receive surgery. To enable a comparison between procedures we extracted the resource use (e.g.

number of extra hospital visits) rather than the actual cost from literature. The resource use was multiplied by standard unit prices for each procedure, ensuring a similar calculation of costs across operations. When available, unit prices were derived from the Dutch guideline for costing research.[13] Otherwise, unit prices were obtained from hospital fees. We excluded medication costs since this was often not reported or the reporting lacked detailed information necessary for our model. Costs were calculated in Euros (€) and based on the 2019 price level.

Operating time

Operating time for all surgical procedures was extracted from literature to weigh the impact of surgery against the time needed to perform the surgery (see analysis). Operating time was considered to be the total time the patient was in the operating theatre, including anaesthesia and surgery (skin-to-skin) time, and was extracted from literature. To validate these data, we compared them with the empirical data provided by two hospitals. Furthermore, in the online available framework, the operating time can be adjusted to match operating times for a specific setting.

Analysis

We calculated the loss of quality of life (in utilities) and extra costs per week delay of surgery based on the obtained utility values and costs. Subsequently, we calculated the net monetary loss, which is defined as the total loss of waiting another week for surgery, expressed in monetary terms. The net monetary loss is calculated by multiplying the loss in quality of life due to waiting one week for surgery by a threshold value, and subsequently the extra costs of waiting another week for surgery are added. We used a threshold value of €20,000 per year of full health, as recommended for conditions with a relatively low burden of disease by the Dutch guidelines for cost-effectiveness (Figure 1c).[13] As an example, let's assume a surgical procedure leads to a 0.2 gain in utility and a decrease in the patient's healthcare expenses of €50 per week. Delaying this procedure for one week results in a net monetary loss of $\left(0.2 \times {}^{1}/_{52} \times €20.000\right) + €50 = €127$. The procedure with the highest net monetary loss therewith provides the most 'value' when prioritized. Subsequently, we also took into account the operating time since more patients can benefit from procedures with short operating times given a fixed OR capacity. For example, when a surgical procedure "X" can be performed twice in the timeframe of procedure "Y", procedure "Y" has to result in twice as much value to have a similar value in the same OR time (Figure 1d). Therefore, the net monetary loss per week was weighted for the operating time, resulting in the net monetary loss per week per OR minute.

Last, we calculated the impact of postponing these elective surgeries during one of the COVID-19 waves, assuming 30% delay in these 13 elective surgeries over a 3 month period as compared to the year before. We calculated the impact of postponing elective surgeries in total costs and total net monetary loss.

Empirical example

To illustrate how our framework works and can be used in clinical practice, we applied it on real world data from a large regional hospital in The Netherlands. Data used from this hospital comprise the actual numbers of patients waiting for each of the 13 included procedures on June 30 in 2020, 2019 and 2018 and the average waiting time for each procedure in these years. Based on these data we calculated the total net monetary loss after the first COVID-19 wave (June 30, 2020) as compared to 2019 and 2018. This was done by multiplying the number of patients that are waiting by the average waiting time and the net monetary loss for that procedure.

Interactive surgical prioritization framework

The decision-analytic models for the elective surgical procedures were wrapped in an interactive web-based framework developed to further stimulate engagement and discussion between the relevant stakeholders, i.e. surgical disciplines, anaesthesiology, other referring medical disciplines, and decision makers. By default, the interactive framework shows the results presented in this paper, but users of the framework can alter some of the parameters (e.g. the operation time) or select procedures relevant to their departments or strategy. In this way the framework can be used on different strategic levels, i.e. department level or hospital level (for decisions across departments). Furthermore, cost prices of the different resources and currencies can be altered to make the framework applicable for other countries. The framework was built using R (version 4.0.2, The R Foundation for Statistical Computing, Vienna, Austria) with shiny (version 1.5.0) and shinydashboard (version 0.7.1) packages.[14,15] The interactive framework is available via https://stanwijn.shinyapps.io/priORitize/

Patient and Public Involvement

There was no patient or public involvement in the study.

Results

Quality of life

The highest loss in quality of life due to delayed surgery was found for total hip replacement (utility of 0.27, i.e. 99 days lost in perfect health when waiting for a year), followed by total shoulder and knee replacement (utilities of 0.22 and 0.22, i.e. 80 days lost in perfect health when waiting for a year), respectively (Table 2). The lowest loss in quality of life was found for arthroscopic partial meniscectomy (utility of 0.05, i.e. 18 days lost in perfect health when waiting for a year), see also Figure 2a. For sphincteroplasty, the male sling procedure, and the tension-free vaginal tape procedure utility values were not available in literature.

Table 2. Overview of the data in the surgical prioritization framework.

Surgical procedure	Surgical specialty	Operating time (min)	Utility pre-surgery	Utility post-surgery	Δ Utility	Cost per week (€)	NML per week (€)	NML by operating time (€)	References Operating time	References Resource use	References Quality of life
Inguinal hernia repair	General surgery	54	0.78	0.88	0.1	€ 0	-€ 38	-€ 0.7	[22]	[23,24]	[25]
Laparoscopic sleeve gastrectomy	General surgery	71	0.73	0.87	0.14	€ 31	-€ 85	-€ 1.2	[26]	[27–31]	[32,33]
laparoscopic Roux-and-Y gastric bypass	General surgery	82	0.75	0.87	0.12	€ 31	-€ 77	-€ 0.9	[26]	[27–31]	[32,33]
Partial colectomy – Non-acute Crohn's disease	Gastrointestinal surgery	180	0.75	0.95	0.2	€ 17	-€ 94	-€ 0.5	[34]	[35–38]	[39–41]
Partial colectomy –	Gastrointestinal surgery	180	0.84	0.96	0.12	€ 16	-€ 62	-€ 0.3	[34]	[35–38]	[39–41]

Ulcerative colitis											
Sphincteroplasty	Gastrointestinal surgery	180	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	[42]	n.a.	n.a.
Total hip replacement	Orthopaedic surgery	150	0.52	0.79	0.27	€ 10	-€ 114	-€ 0.8	Expert opinion	[43,44]	[45–48]
Total knee replacement	Orthopaedic surgery	106	0.51	0.73	0.22	€ 10	-€ 95	-€ 0.9	[49]	[44,50]	[51]
Total shoulder replacement	Orthopaedic surgery	181	0.66	0.89	0.22	n.a.	n.a.	n.a.	[52,53]	[54]	[55]
Arthroscopic partial meniscectomy	Orthopaedic surgery	50	0.75	0.8	0.05	-€ 2	-€ 18	-€ 0.3	Expert opion	[56]	[56]
Septoplasty	Otorhinolaryngology	61	0.83	0.89	0.06	-€ 1	-€ 22	-€ 0.4	[57]	[58]	[58]
Male sling procedure	Urology	59	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	[59]	n.a.	n.a.
Tension-free vaginal tape procedure	Urology	56	0.78	n.a.	n.a.	n.a.	n.a.	n.a.	[60]	n.a.	[60]

Min: minutes, n.a.: not available, NML: net monetary loss.

[insert Figure 2]

Cost

Delay of both LSG and LRYGB bariatric surgery resulted in the highest costs (€31 pp per week), followed by partial colectomy for non-acute Crohn's disease (€17 pp per week), and ulcerative colitis (€16 pp per week). Delay of arthroscopic partial meniscectomy was found to result in the lowest costs (-€2 pp per week), see also Figure 2b. For sphincteroplasty, total shoulder replacement, male sling procedure, and tension-free vaginal tape procedure, no literature was available to determine the extra resource use due to waiting for surgery.

Net monetary loss

Combining the loss in quality of life and extra costs resulted in a calculation of the net monetary loss per week. Total hip replacement was found to result in the highest loss per week of delay (€114 per week per procedure), followed by total knee replacement (€95 per week per procedure), and partial colectomy for non-acute Crohn's disease (€94 per week per procedure). Arthroscopic partial meniscectomy appears to result in the lowest loss per week (€18 per week per procedure), see also Figure 2c. It should be noted that the net monetary loss could only be calculated for procedures for which we could find information regarding the quality of life and costs in the literature.

Net monetary loss weighted by operating time

When the OR time per procedure is taken into account, the net monetary loss per week per OR minute shows that LSG provides the most value (€1.2 per week per OR minute), followed by LRYGB (€0.9 per week per OR minute), and total knee replacement (€0.9 per week per OR minute). Arthroscopic partial meniscectomy seems to provide the least value (€0.3 per week per OR minute), see also Figure 2d.

Impact of surgical delay

For the 13 included elective surgeries, we conservatively estimated that 30% was delayed for 3 months as compared to the total number that was performed in the year before Covid-19 (i.e. 27,500 elective surgeries for the 13 included procedures). In total, a 30% delay in the 13 selected elective surgical procedures resulted in €0.3 million extra costs for the healthcare system and a total impact on both cost and quality of life of €3.6 million. The impact of a 10 to 50% surgical delay for each procedure can be found in Supplement S3.

Empirical example

The impact of the COVID-19 crisis was clearly visible in the surgical waiting times of a large regional hospital in The Netherlands (Supplement S4). After the first COVID-19 wave (i.e. on June 30, 2020), 624 patients were waiting for one of the 13 included procedures, while on the same day in 2019 and 2018, 291 and 257 patients were waiting. As a consequence, the total net monetary loss after the first wave was €873.504, while the total net monetary losses were €172.664 and €124.224 in 2019 and 2018. Compared to June 30, 2019 and 2018, the total net monetary after the first wave increased with 506% (€700.840) and with 703% (€749.280), respectively.

Discussion

We developed a surgical prioritization framework that provides information that can be used to set priorities in elective surgeries. For example, the highest loss in quality of life due to delayed surgery was found for total hip replacement (utility of 0.27, i.e. 99 days lost in perfect health when waiting for a year); the lowest for arthroscopic partial meniscectomy (utility of 0.05, i.e. 18 days lost in perfect health when waiting for a year). Costs of surgical delay were highest for LSG and LRYGB (€31/pp per week) and lowest for arthroscopic partial meniscectomy (-€2/pp per week). Total hip replacement and total knee replacement resulted in the highest net monetary losses per week (€114 and €95, respectively), while septoplasty and arthroscopic partial meniscectomy had a net monetary loss per week of €22 and €18, respectively. In case we assumed that 30% of the 13 included procedures were delayed over a 3 month period as compared to the total numbers of procedures performed a year earlier, the delay resulted in €0.3 million extra costs for the Dutch healthcare system and a total impact on both cost and quality of life (net monetary loss) of €3.6 million. Data from a large regional hospital in The Netherlands show that more than twice as many patients were waiting for one of the 13 modelled operative procedures after the first COVID-19 wave as compared to 2019 (624 versus 291 patients, respectively). Consequently, the extra net monetary loss caused by these waiting times was €700.840, which is an increase of 506% compared to 2019.

Several other models to study the effect of delayed surgery and to inform surgical recovery plans have been developed. Degeling et al. for example,[16] developed a model to estimate the impact of delayed cancer diagnosis and treatment on survival outcomes and healthcare costs based on a shift in the cancer disease stage at treatment initiation. They showed that a conservative 3-month delay in cancer diagnosis and treatment due to the COVID-19 pandemic, results in an excess health cost of $12 million in Australia over 5 years for the in 2020 diagnosed patients for 4 cancers. Gravesteijn et al.[17] also developed a model that supports prioritization of care. They, however, focused on semi-elective surgeries, including cardiothoracic, oncological and transplantation surgery, whereas we

focused on elective surgeries. Needless to say that cancer patients and patients awaiting organ transplantation have a completely different profile as far as prognosis of their disease on the one hand and burden of awaiting treatment, on the other, is concerned. Furthermore, they used the global burden of disease by the WHO to estimate the QALY for 1/3 of the surgeries, and for the other 2/3 they used estimates by an expert panel. Our quality of life data are based on literature data from comparative studies using validated quality of life measures, which is in agreement with the ISPOR recommendation to use health-utility data collected from patients.[18] Wang et al.[19] developed a framework to model surgical backlog recovery. In contrast to our model, they did not include quality of life assessment to guide prioritization of care. They used available resources and bed capacity that are adjustable to other contexts, aiding region-specific decision-making. The COVIDSurg Collaborative[2] and Brandman et al.[20] separately developed models to predict the size of the backlog and time needed to restore this backlog. Although these models are different from the present framework, combining both perspectives might result in a comprehensive context specific policy to clear the surgical backlog.

The major strength of our approach is that the data used from literature are completely transparent in the online framework, and that it can easily be adapted according to local settings (e.g. regarding operation times) and new available evidence. Our model was built with high-quality QoL- and cost data that were derived from randomised controlled trials or comparative studies. We had the unique opportunity to cross validate our results to a national study by the Dutch Institute for Public Health and the Environment and empirical data from a large local hospital.[10] The concordance appeared to be very high with more than 75% overlap. Furthermore, by calculating the net monetary losses per week weighed by OR minute we were able to make a comparison between procedures and surgical disciplines based on the surgery time. This provides new insights on how to allocate valuable surgery time when comparing these operations, to maximize value.

Some potential limitations should also be discussed. First, we used average data from literature rather than patient-level data, which could impact the applicability of our results to the individual patient. However, our goal was to develop a practical framework to support priority setting able to generalize and compare on department and surgery level instead. The model is therefore useful in general during the COVID-19 pandemic as well as for policy-making in striving for quality-driven healthcare.

Second, we did not yet take into account other related factors such as ICU or personnel capacity, the number of beds available, the risk of exposing patients to perioperative COVID-19 infection, or psychological consequences. This was outside the scope of this paper but can be added in a future model, and of course these factors can be taken into account in the individual trade-off.

Third, impact of waiting on medication costs (for example pain medication that patients need while waiting for surgery), could not be taken into account because they were either not reported in literature or not described in enough detail to be suitable for inclusion in the model. In order to be able to take medication costs into account, better reporting of cost data, i.e. categorization of cost data, in clinical studies is needed. Furthermore, it could be expected that some patients need extra home care or had a prolonged stay in a nursing home because they are waiting for surgery. These costs were not reported in literature and were therefore not included in the model. Consequently, the total cost presented are an underestimation of the real cost.

Fourth, besides impact on quality of life, delayed surgery may have a variety of consequences regarding the deterioration of the disease ranging from 'no harm' (varices, inguinal hernia) to 'complications' (easy or difficult to treat, medically or surgically: Crohn's disease, ulcerative colitis) to disease-related death. Currently, high-quality data regarding the consequences of the delay of surgery on deterioration are lacking and could therefore not be included in our model. Because of the elective nature of the included procedures, we believe that deterioration with high impact (like disease-related death) will be limited. However, if this COVID-19 pandemic will prove that delaying

the included procedures do lead to high impact deterioration it is necessary to include the consequences of delaying surgery, the model can be adapted accordingly.

Fifth, so far, we only modelled 13 elective surgical procedures whereas there are many more. Since we developed an online framework, new data can easily be added to inform future decision making, for example additional high quality data comparing surgery to watchful waiting or non-surgical care. Others can also provide us with relevant information on other procedures, which we will check on consistency and validity, before adding them to the online framework.

Sixth, for some procedures no data on quality of life or costs were available in literature. The fact that no relevant data were retrieved from literature for sphincteroplasty , male sling procedure, and tension-free vaginal tape procedure illustrates how difficult it is, and will be, to calculate the added value of these procedures. It renders this type of surgery 'vulnerable' in strategic discussions, but also stimulates groups active in this complex field to come up with data in support of continuing this type of operations. We are, however, aware of research projects that will follow the patients currently 'waiting' due to the backlog of the pandemic.[21] Hopefully, these projects will provide us with more accurate data, which are critical to obtain reliable estimates.

The ongoing pandemic is having a collateral damage effect on health care and the delivery of surgical care to millions of patients worldwide. This is an effect that most certainly will persist for years to come. It is to be expected that cancer and other acute surgery, if cancelled during the pandemic, will be prioritized in most settings, whereas the impact on other elective surgeries for benign conditions will be cumulative, adding to the existing waiting times. Governments and other policy makers will be requested to fund substantial increases in surgical volume to clear backlogs, and this framework may help them to prioritize on evidence regarding QoL and cost savings rather than on a mixture of numbers and expert opinion.

When addressing the backlog of postponed elective surgeries, it is tempting to start with surgeries that cause a high net monetary loss when delayed on the one hand and have large volumes on the

other. However, as we look at bariatric surgery, we see a discrepancy between population impact and net monetary loss per OR minute. Although bariatric surgery has one of the highest net monetary losses of all procedures described in this paper, it has the lowest impact on population level due to small volumes. Also, when resuming total knee and total hip replacement first, huge numbers of patients need to be operated taking a lot of valuable OR time, while for bariatric surgery only a small number of patients needs to be operated. Therefore, we would like to emphasize that objective measures are indispensable for fair and justifiable prioritization of surgeries, and that these choices are preferably based on the net monetary loss per OR minute. Such medical care prioritisation data may add to future discussions on “appropriate use” of health care budgets.

In conclusion, our online framework can be used in deciding how to address the postponed elective surgeries after the COVID-19 pandemic. Furthermore, the model will also be useful during possible future repeated waves of COVID-19 or in the long-term as it provides relevant information regarding an efficient distribution of OR time.

Figure legends

Figure 1: Overview of the methods used. 1a: Loss in quality of life (QoL) due to delayed or postponed surgery was calculated by extracting the QoL before surgery from the QoL after surgery and multiplying this with the duration of the delay (one week in our analyses). 1b: The costs (in €) associated with waiting for surgery were calculated by extracting the average costs after surgery from the average costs before surgery and multiplying this with the duration of the delay (one week in our analyses). 1c: The net monetary loss (monetary measure to calculate the total societal loss of delaying surgery) was calculated by multiplying the loss in QoL by the willingness to pay (€ 20,000) and adding the extra costs associated with waiting for surgery. The willingness to pay represents the amount of money society is willing to pay for one year in full health. 1d: Surgery associated net monetary loss per week divided by operating time. Relevant when trying to optimize the operating schedule. During a two hour surgery, also two operations of one hour could be performed. In other words, the two hour surgery needs to be associated with twice as much NML as the 1 hour surgeries to be as worthwhile to perform.

Figure 2: Overview of results. 2a: Loss in quality of life (QoL) due to delayed or postponed surgery expressed as a utility score. A utility reflects QoL on a 0 to 1 scale, with 0 representing death and 1 representing full health. 2b: Extra health care expenditure due to waiting for surgery. 2c: The net monetary loss combines QoL and costs due to waiting for surgery, it is therefore the total loss of waiting another week for surgery, expressed in monetary terms. 2d: Surgery associated net monetary loss per week devided by operating time (i.e. it reflects the total cost per week per OR minute).

Declarations

Competing interests

MR had financial support by means of a VICI grant from NWO (Dutch Research Council) for the submitted work, the other authors had no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work

Licence

The Corresponding Author has the right to grant on behalf of all authors and does grant on behalf of all authors, an exclusive licence (or non exclusive for government employees) on a worldwide basis to the BMJ Publishing Group Ltd ("BMJ"), and its Licencees to permit this article (if accepted) to be published in The BMJ's editions and any other BMJ products and to exploit all subsidiary rights, as set out in our licence.

Contributors and sources

MR, SW, JG, HG, MS and TG have contributed to the conception and design of the study. All authors have contributed to the final design of the paper. Modelling was performed by SW, SM, RV, MS, TG, CM, MJ, IS and NvdB. Model input and feedback was received from RvdP, BB, HG, CT, MS, CR, SvdG, TvT, RP, JR and NS. MR, SW, MS and TG drafted the manuscript. The online framework as developed by SW. All authors have made contributions to the drafting and revising of the article. All authors have read, reviewed and approved the final version of the manuscript before submission.

Role of the funding source

The study was funded by NWO (Dutch Research Council), VICI-project Rovers, project number 91818617. The funder had no role in the study design; in the collection, analysis, and interpretation of data; in the writing of the report; and in the decision to submit the article for publication. All authors were independent from the funder. All authors had full access to all of the data and can take responsibility for the integrity of the data and the accuracy of the data analysis. There was no commercial involvement in the study.

Transparancy

The lead authors affirm that the manuscript is an honest, accurate, and transparent account of the study being reported; and that no important aspects of the study have been omitted.

Data availability statement

All data used in this study were derived from sources available in the public domain. For references please refer to Table 2 or the online tool: https://stanwijn.shinyapps.io/priORitize/

References

1. Søreide K, Hallet J, Matthews JB, Schnitzbauer AA, Line PD, Lai PBS, et al. Immediate and long-term impact of the COVID-19 pandemic on delivery of surgical services. Br. J. Surg. John Wiley and Sons Ltd; 2020. p. 1250–61.

2. Nepogodiev D, Omar OM, Glasbey JC, Li E, Simoes JFF, Abbott TEF, et al. Elective surgery cancellations due to the COVID-19 pandemic: global predictive modelling to inform surgical recovery plans. Br. J. Surg. 2020;107(11):1440–9.

3. Fowler AJ, Dobbs TD, Wan YI, Laloo R, Hui S, Nepogodiev D, et al. Resource requirements for reintroducing elective surgery during the COVID-19 pandemic: modelling study. Br. J. Surg. 2021;108(1):97–103.

4. Campbell D. The NHS elective recovery plan: how it aims to clear the surgery backlog. The Guardian. 2022;02–7.

5. Nepogodiev D, Abbott TE, Ademuyiwa AO, AlAmeer E, Bankhead-Kendall BK, Biccard BM, et al. Projecting COVID-19 disruption to elective surgery. Lancet. 2022;399(10321):233–4.

6. Brody H. Medicine's Ethical Responsibility for Health Care Reform — The Top Five List. N. Engl. J. Med. 2010;362(4):283–5.

7. Morden NE, Colla CH, Sequist TD, Rosenthal MB. Choosing Wisely — The Politics and Economics of Labeling Low-Value Services. N. Engl. J. Med. 2014;370(7):589–92.

8. Caro JJ, Briggs AH, Siebert U, Kuntz KM. Modeling Good Research Practices—Overview: A Report of the ISPOR-SMDM Modeling Good Research Practices Task Force-1. Value Heal. 2012;15(6):796–803.

9. Dutch Healthcare Authority (NZa). Urgentielijst medisch-specialistische zorg - Nederlandse Zorgautoriteit [Internet]. [cited 2021 Mar 18]. Available from: https://puc.overheid.nl/nza/doc/PUC_306624_22/1/

10. Giessen A van, Wit A de, Brink C van den, Degeling K, Deuning C, Eeuwijk J, et al. Impact of the first wave of COVID-19 on regular healthcare and health [Internet]. 2020 [cited 2021 Mar 18].

p. 158. Available from: https://www.rivm.nl/en/bibcite/reference/337271

11. Rabin R, De Charro F. EQ-5D: A measure of health status from the EuroQol Group. In: Annals of Medicine. Royal Society of Medicine Press Ltd; 2001. p. 337–43.

12. Versteegh M, M. Vermeulen K, M. A. A. Evers S, de Wit GA, Prenger R, A. Stolk E. Dutch Tariff for the Five-Level Version of EQ-5D. Value Heal. 2016;19(4):343–52.

13. Hakkaart-van Roijen L, van der Linden N, Bouwmans C, Kanters T, Swan Tan S. Kostenhandleiding: Methodologie van kostenonderzoek en referentieprijzen voor economische evaluaties in de gezondheidszorg [Internet]. Dutch Natl. Heal. Care Inst. 2016. p. 1–73. Available from: https://www.zorginstituutnederland.nl/over-ons/publicaties/publicatie/2016/02/29/richtlijn-voor-het-uitvoeren-van-economische-evaluaties-in-de-gezondheidszorg

14. Chang W, Cheng J, Allaire JJ, Xie Y MJ. shiny: Web Application Framework for R version 1.3.2 from CRAN [Internet]. Compr. R Arch. Netw. 2017 [cited 2021 Mar 26]. Available from: https://rdrr.io/cran/shiny/

15. Chang W, Ribeiro BB. Package “ShinyDashboard”: Create Dashboards with “Shiny” [Internet]. Comprehensive R Archive Network (CRAN); 2018 [cited 2021 Mar 26]. p. 27. Available from: https://cran.r-project.org/package=shinydashboard

16. Degeling K, Baxter NN, Emery J, Jenkins MA, Franchini F, Gibbs P, et al. An inverse stage-shift model to estimate the excess mortality and health economic impact of delayed access to cancer services due to the COVID-19 pandemic. Asia. Pac. J. Clin. Oncol. 2021;ajco.13505.

17. Gravesteijn B, Krijkamp E, Busschbach J, Geleijnse G, Helmrich IR, Bruinsma S, et al. Minimizing Population Health Loss in Times of Scarce Surgical Capacity During the Coronavirus Disease 2019 Crisis and Beyond: A Modeling Study. Value Heal. 2021;1–10.

18. Brazier J, Ara R, Azzabi I, Busschbach J, Chevrou-Séverac H, Crawford B, et al. Identification, Review, and Use of Health State Utilities in Cost-Effectiveness Models: An ISPOR Good Practices for Outcomes Research Task Force Report. Value Heal. 2019;22(3):267–75.

19. Wang J, Vahid S, Eberg M, Milroy S, Milkovich J, Wright FC, et al. Clearing the surgical backlog caused by COVID-19 in Ontario: A time series modelling study. CMAJ. 2020;192(44):E1347–56.

20. Brandman DM, Leck E, Christie S. Modelling the backlog of COVID-19 cases for a surgical group. Can. J. Surg. 2020;63(5):E391–2.

21. TRACE II: Patiëntuitkomsten na uitgestelde electieve operaties tijdens de COVID-19 pandemie - ZonMw [Internet]. [cited 2021 Mar 18]. Available from: https://www.zonmw.nl/nl/over-zonmw/coronavirus/programmas/project-detail/covid-19-programma/trace-ii-outcome-in-patients-undergoing-postponed-elective-surgery-during-the-covid-19-pandemic/

22. Langeveld HR, van't Riet M, Weidema WF, Stassen LPS, Steyerberg EW, Lange J, et al. Total Extraperitoneal Inguinal Hernia Repair Compared With Lichtenstein (the LEVEL-Trial). Ann. Surg. 2010;251(5):819–24.

23. Stroupe KT, Manheim LM, Luo P, Giobbie-Hurder A, Hynes DM, Jonasson O, et al. Tension-Free Repair Versus Watchful Waiting for Men with Asymptomatic or Minimally Symptomatic Inguinal Hernias: A Cost-Effectiveness Analysis. J. Am. Coll. Surg. 2006;203(4):458–68.

24. Fitzgibbons RJ, Giobbie-Hurder A, Gibbs JO, Dunlop DD, Reda DJ, McCarthy M, et al. Watchful Waiting vs Repair of Inguinal Hernia in Minimally Symptomatic Men. JAMA. 2006;295(3):285.

25. Chard J, Kuczawski M, Black N, van der Meulen J. Outcomes of elective surgery undertaken in independent sector treatment centres and NHS providers in England: audit of patient outcomes in surgery. BMJ. 2011;343(oct19 1):d6404–d6404.

26. Dogan K, Kraaij L, Aarts EO, Koehestanie P, Hammink E, van Laarhoven CJHM, et al. Fast-Track Bariatric Surgery Improves Perioperative Care and Logistics Compared to Conventional Care. Obes. Surg. 2015;25(1):28–35.

27. Poelemeijer YQM, Liem RSL, Nienhuijs SW. A Dutch Nationwide Bariatric Quality Registry: DATO. Obes. Surg. 2018;28(6):1602–10.

28. Espallardo O, Busutil R, Torres A, Zozaya N, Villoro R, Hidalgo-Vega Á. The Impact of Severe Obesity on Healthcare Resource Utilisation in Spain. Obes. Surg. 2017;27(8):2058–66.

29. Backes CF, Lopes E, Tetelbom A, Heineck I. Medication and nutritional supplement use before and after bariatric surgery. Sao Paulo Med. J. 2016;134(6):491–500.

30. Khan SS, Ning H, Wilkins JT, Allen N, Carnethon M, Berry JD, et al. Association of Body Mass Index With Lifetime Risk of Cardiovascular Disease and Compression of Morbidity. JAMA Cardiol. 2018;3(4):280.

31. Segal JB, Clark JM, Shore AD, Dominici F, Magnuson T, Richards TM, et al. Prompt Reduction in Use of Medications for Comorbid Conditions After Bariatric Surgery. Obes. Surg. 2009;19(12):1646–56.

32. Sendi P, Brunotte R, Potoczna N, Branson R, Horber FF. Health-Related Quality of Life in Patients with Class II and Class III Obesity. Obes. Surg. 2005;15(7):1070–6.

33. Biter LU, van Buuren MMA, Mannaerts GHH, Apers JA, Dunkelgrün M, Vijgen GHEJ. Quality of Life 1 Year After Laparoscopic Sleeve Gastrectomy Versus Laparoscopic Roux-en-Y Gastric Bypass: a Randomized Controlled Trial Focusing on Gastroesophageal Reflux Disease. Obes. Surg. 2017;27(10):2557–65.

34. Harrison OJ, Smart NJ, White P, Brigic A, Carlisle ER, Allison AS, et al. Operative Time and Outcome of Enhanced Recovery After Surgery After Laparoscopic Colorectal Surgery. JSLS J. Soc. Laparoendosc. Surg. 2014;18(2):265–72.

35. Rubin GP, Hungin APS, Kelly PJ, Ling J. Inflammatory bowel disease: epidemiology and management in an English general practice population. Aliment. Pharmacol. Ther. 2000;14(12):1553–9.

36. Miehsler W, Weichselberger M, Öfferlbauer-Ernst A, Dejaco C, Reinisch W, Vogelsang H, et al. Which patients with IBD need psychological interventions? A controlled study. Inflamm. Bowel Dis. 2008;14(9):1273–80.

37. Thia KT, Sandborn WJ, Harmsen WS, Zinsmeister AR, Loftus E V. Risk Factors Associated With Progression to Intestinal Complications of Crohn’s Disease in a Population-Based Cohort. Gastroenterology. 2010;139(4):1147–55.

38. Hsu Y-C, Wu T-C, Lo Y-C, Wang L-S. Gastrointestinal complications and extraintestinal manifestations of inflammatory bowel disease in Taiwan: A population-based study. J. Chinese Med. Assoc. 2017;80(2):56–62.

39. Stark RG, Reitmeir P, Leidl R, König H-H. Validity, reliability, and responsiveness of the EQ-5D in inflammatory bowel disease in Germany. Inflamm. Bowel Dis. 2010;16(1):42–51.

40. Huppertz-Hauss G, Høivik ML, Langholz E, Odes S, Småstuen M, Stockbrugger R, et al. Health-related Quality of Life in Inflammatory Bowel Disease in a European-wide Population-based Cohort 10 Years After Diagnosis. Inflamm. Bowel Dis. 2015;21(2):337–44.

41. Penner RM, Tandon P. Management of Crohn disease after surgical resection - UpToDate [Internet]. Up To Date. 2017 [cited 2021 Apr 8]. Available from: https://www.uptodate.com/contents/management-of-crohn-disease-after-surgical-resection?search=crohn disease surgical treatment&topicRef=86198&source=see_link%0Ahttps://www.uptodate.com/contents/management-of-crohn-disease-after-surgical-resection?source=h

42. Ratto C, Litta F, Donisi L, Parello A. Fistulotomy or fistulectomy and primary sphincteroplasty for anal fistula (FIPS): a systematic review. Tech. Coloproctol. 2015;19(7):391–400.

43. Fordham R, Skinner J, Wang X, Nolan J. The economic benefit of hip replacement: a 5-year follow-up of costs and outcomes in the Exeter Primary Outcomes Study. BMJ Open. 2012;2(3):e000752.

44. Bozic KJ, Stacey B, Berger A, Sadosky A, Oster G. Resource utilization and costs before and after total joint arthroplasty. BMC Health Serv. Res. 2012;12(1):73.

45. Johnson EC, Horwood J, Gooberman-Hill R. Conceptualising time before surgery: The experience of patients waiting for hip replacement. Soc. Sci. Med. 2014;116:126–33.

46. Konopka JF, Lee Y, Su EP, McLawhorn AS. Quality-Adjusted Life Years After Hip and Knee Arthroplasty. JBJS Open Access. 2018;3(3):e0007.

47. Rolfson O, Dahlberg LE, Nilsson J-å., Malchau H, Garellick G. Variables determining outcome in

total hip replacement surgery. J. Bone Joint Surg. Br. 2009;91-B(2):157–61.

48. Gordon M, Greene M, Frumento P, Rolfson O, Garellick G, Stark A. Age- and health-related quality of life after total hip replacement. Acta Orthop. 2014;85(3):244–9.

49. Ravi B, Jenkinson R, O'Heireamhoin S, Austin PC, Aktar S, Leroux TS, et al. Surgical duration is associated with an increased risk of periprosthetic infection following total knee arthroplasty: A population-based retrospective cohort study. EClinicalMedicine. 2019;16:74–80.

50. Picard F, Deakin A, Balasubramanian N, Gregori A. Minimally invasive total knee replacement: techniques and results. Eur. J. Orthop. Surg. Traumatol. 2018;28(5):781–91.

51. Jansson K-Å, Granath F. Health-related quality of life (EQ-5D) before and after orthopedic surgery. Acta Orthop. 2011;82(1):82–9.

52. Dunn JC, Lanzi J, Kusnezov N, Bader J, Waterman BR, Belmont PJ. Predictors of length of stay after elective total shoulder arthroplasty in the United States. J. Shoulder Elb. Surg. 2015;24(5):754–9.

53. Padegimas EM, Hendy BA, Lawrence C, Devasagayaraj R, Zmistowski BM, Abboud JA, et al. An analysis of surgical and nonsurgical operating room times in high-volume shoulder arthroplasty. J. Shoulder Elb. Surg. 2017;26(6):1058–63.

54. Grobet CE, Glanzmann MC, Eichler K, Rickenbacher D, Meier F, Brunner B, et al. Cost-utility analysis of total shoulder arthroplasty: A prospective health economic study using real-world data. J. Shoulder Elb. Surg. 2021;1.

55. Evans J, Dattani R, Ramasamy V, Patel V. Responsiveness of the EQ-5D-3L in elective shoulder surgery: Does it adequately represent patient experience? J. Orthop. Surg. 2018;26(2).

56. Van De Graaf VA, Van Dongen JM, Willigenburg NW, Noorduyn JCA, Butter IK, De Gast A, et al. How do the costs of physical therapy and arthroscopic partial meniscectomy compare? A trial-based economic evaluation of two treatments in patients with meniscal tears alongside the ESCAPE study. Br. J. Sports Med. 2020;54(9):538–46.

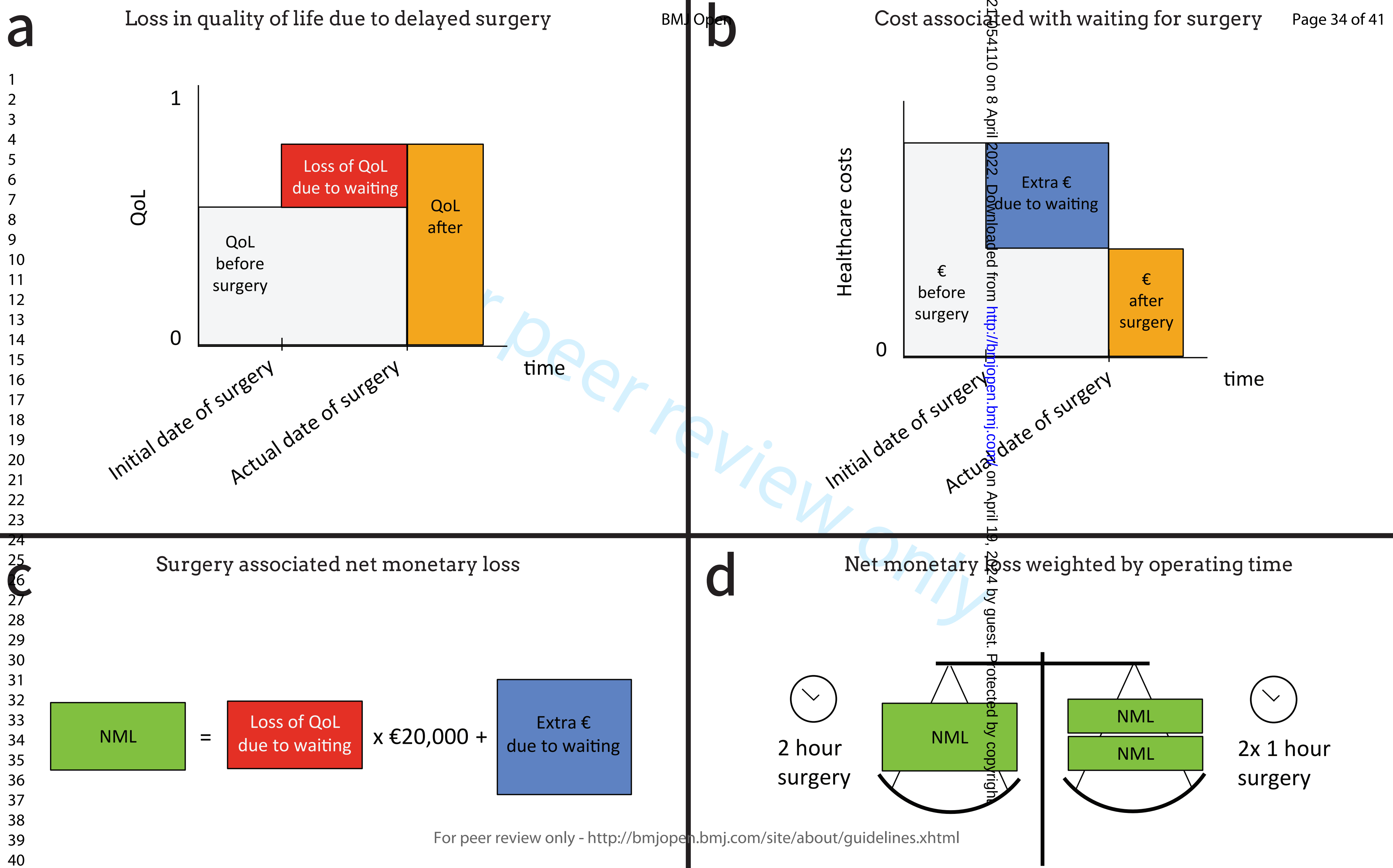
57. Menezes AS, Guimarães JR, Breda M, Vieira V, Dias L. Septal and turbinate surgery: is

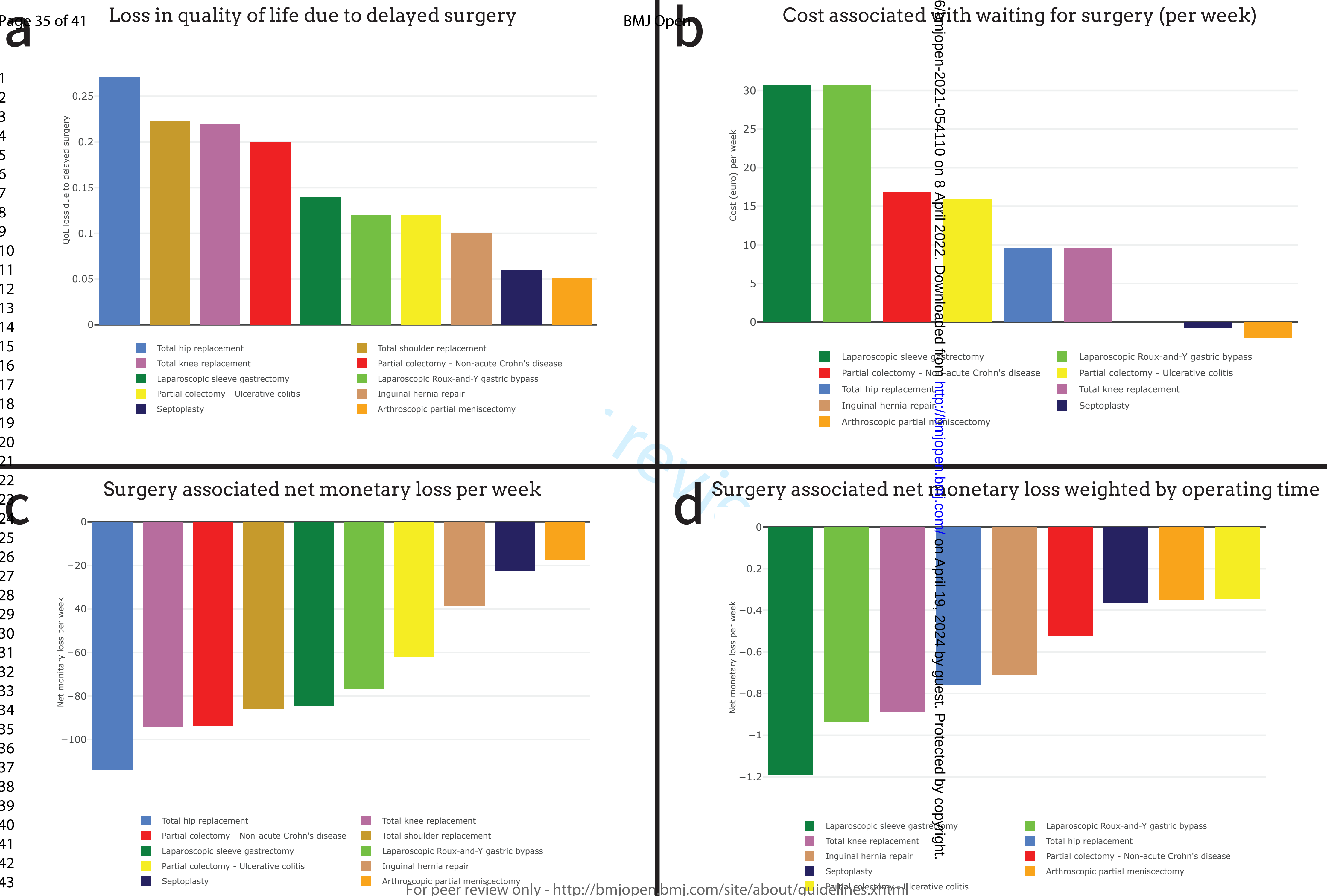
overnight essential? Eur. Arch. Oto-Rhino-Laryngology. 2018;275(1):131–8.

58. van Egmond MMHT, Rovers MM, Hannink G, Hendriks CTM, van Heerbeek N. Septoplasty with or without concurrent turbinate surgery versus non-surgical management for nasal obstruction in adults with a deviated septum: a pragmatic, randomised controlled trial. Lancet. 2019;394(10195):314–21.

59. Leruth J, Waltregny D, de Leval J. The Inside-Out Transobturator Male Sling for the Surgical Treatment of Stress Urinary Incontinence After Radical Prostatectomy: Midterm Results of a Single-Center Prospective Study. Eur. Urol. 2012;61(3):608–15.

60. Manca A, Sculpher MJ, Ward K, Hilton P. A cost-utility analysis of tension-free vaginal tape versus colposuspension for primary urodynamic stress incontinence. BJOG. 2003;110(3):255–62.


a
Loss in quality of life due to delayed surgery
1
0
QoL
Loss of QoL due to waiting
QoL after
QoL before surgery
time
Initial date of surgery
Actual date of surgery
b
Cost associated with waiting for surgery
Healthcare costs
0
Extra € due to waiting
€ before surgery
€ after surgery
time
Initial date of surgery
Actual date of surgery
c
Surgery associated net monetary loss
NML
=
Loss of QoL due to waiting
x €20,000 +
Extra € due to waiting
d
Net monetary loss weighted by operating time
2 hour surgery
NML
NML
NML
2x 1 hour surgery


a
Loss in quality of life due to delayed surgery
QoL loss due to delayed surgery
0.25
0.2
0.15
0.1
0.05
0
Total hip replacement
Total shoulder replacement
Total knee replacement
Partial colectomy - Non-acute Crohn's disease
Laparoscopic sleeve gastrectomy
Laparoscopic Roux-and-Y gastric bypass
Partial colectomy - Ulcerative colitis
Inguinal hernia repair
Septoplasty
Arthroscopic partial meniscectomy
b
Cost associated with waiting for surgery (per week)
Cost (euro) per week
30
25
20
15
10
5
0
Laparoscopic sleeve gastrectomy
Laparoscopic Roux-and-Y gastric bypass
Partial colectomy - Non-acute Crohn's disease
Partial colectomy - Ulcerative colitis
Total hip replacement
Total knee replacement
Inguinal hernia repair
Septoplasty
Arthroscopic partial meniscectomy
c
Surgery associated net monetary loss per week
Net monitary loss per week
0
−20
−40
−60
−80
−100
Total hip replacement
Total knee replacement
Partial colectomy - Non-acute Crohn's disease
Total shoulder replacement
Laparoscopic sleeve gastrectomy
Laparoscopic Roux-and-Y gastric bypass
Partial colectomy - Ulcerative colitis
Inguinal hernia repair
Septoplasty
Arthroscopic partial meniscectomy
d
Surgery associated net monetary loss weighted by operating time
Net monetary loss per week
0
−0.2
−0.4
−0.6
−0.8
−1
−1.2
Laparoscopic sleeve gastrectomy
Laparoscopic Roux-and-Y gastric bypass
Total knee replacement
Total hip replacement
Inguinal hernia repair
Partial colectomy - Non-acute Crohn's disease
Septoplasty
Arthroscopic partial meniscectomy
Partial colectomy - Ulcerative colitis

CHEERS 2022 Checklist

Title			
Title	1	Identify the study as an economic evaluation and specify the interventions being compared.	the study is identified as decision analytical modelling study
Abstract			
Abstract	2	Provide a structured summary that highlights context, key methods, results, and alternative analyses.	the abstract is structured and includes objective, design, setting, outcome measures, results and conclusions
Introduction			
Background and objectives	3	Give the context for the study, the study question, and its practical relevance for decision making in policy or practice.	Introduction
Methods			
Health economic analysis plan	**4**	**Indicate whether a health economic analysis plan was developed and where available.**	**n.a.**
Study population	5	Describe characteristics of the study population (such as age range, demographics, socioeconomic, or clinical characteristics).	selected elective procedures paragraph
Setting and location	6	Provide relevant contextual information that may influence findings.	selected elective procedures and empirical example paragraphs
Comparators	7	Describe the interventions or strategies being compared and why chosen.	selected elective procedures paragraph
Perspective	8	State the perspective(s) adopted by the study and why chosen.	costs paragraph
Time horizon	9	State the time horizon for the study and why appropriate.	costs paragraph

(continued)

Discount rate	10	Report the discount rate(s) and reason chosen.	n.a.
Selection of outcomes	11	Describe what outcomes were used as the measure(s) of benefit(s) and harm(s).	quality of life, costs and analysis paragraphs
Measurement of outcomes	12	Describe how outcomes used to capture benefit(s) and harm(s) were measured.	quality of life, costs and analysis paragraphs
Valuation of outcomes	13	Describe the population and methods used to measure and value outcomes.	data acquisition and validation paragraph and appendices
Measurement and valuation of resources and costs	14	Describe how costs were valued.	costs paragraph
Currency, price date, and conversion	15	Report the dates of the estimated resource quantities and unit costs, plus the currency and year of conversion.	costs paragraph and online tool
Rationale and description of model	16	If modelling is used, describe in detail and why used. Report if the model is publicly available and where it can be accessed.	methods section
Analytics and assumptions	17	Describe any methods for analysing or statistically transforming data, any extrapolation methods, and approaches for validating any model used.	methods section
Characterising heterogeneity	18	Describe any methods used for estimating how the results of the study vary for subgroups.	n.a.
Characterising distributional effects	19	Describe how impacts are distributed across different individuals or adjustments made to reflect priority populations.	n.a.

(continued)

Characterising uncertainty	20	Describe methods to characterise any sources of uncertainty in the analysis.	n.a.
Approach to engagement with patients and others affected by the study	21	Describe any approaches to engage patients or service recipients, the general public, communities, or stakeholders (such as clinicians or payers) in the design of the study.	methods
Results			
Study parameters	22	Report all analytic inputs (such as values, ranges, references) including uncertainty or distributional assumptions.	entire results section
Summary of main results	23	Report the mean values for the main categories of costs and outcomes of interest and summarise them in the most appropriate overall measure.	first 4 paragraphs of the results section
Effect of uncertainty	24	Describe how uncertainty about analytic judgments, inputs, or projections affect findings. Report the effect of choice of discount rate and time horizon, if applicable.	n.a.
Effect of engagement with patients and others affected by the study	25	Report on any difference patient/service recipient, general public, community, or stakeholder involvement made to the approach or findings of the study	n.a.
Discussion			

(continued)

Study findings, limitations, generalisability, and current knowledge	26	Report key findings, limitations, ethical or equity considerations not captured, and how these could affect patients, policy, or practice.	discussion section
Other relevant information			
Source of funding	27	Describe how the study was funded and any role of the funder in the identification, design, conduct, and reporting of the analysis	role of the funding source statement
Conflicts of interest	28	Report authors conflicts of interest according to journal or International Committee of Medical Journal Editors requirements.	competing interests statement

From: Husereau D, Drummond M, Augustovski F, et al. Consolidated Health Economic Evaluation Reporting Standards 2022 (CHEERS 2022) Explanation and Elaboration: A Report of the ISPOR CHEERS II Good Practices Task Force. Value Health 2022;25. doi:10.1016/j.jval.2021.10.008

Supplement S2: Search strategy for model data

OR Time / Length of stay after OR

- Disease
- Surgery type
- Length of stay / hospital stay
- Optional: Netherlands, Europe, UK, Germany

Pubmed:

1. “<Disease>” AND “<Surgery type>” FILTER RCT
2. “<Disease>” AND “<Surgery type>” AND (“length of stay” OR “hospital stay”)
3. Patient information folder

Utility scores

- Utility score / EQ5D /Quality of Life
- Disease
- Surgery type
- Conservative treatment / conservative care / watchful waiting
- Optional: Netherlands, Europe, UK, Germany

Pubmed:
“Utility score” OR “EQ5D” OR “Quality of Life” AND

1. “<disease name>” OR “<surgery type>”
2. ”Conservative treatment” OR “Conservative care” OR “Watchful waiting”

Costing data

- Costs / Resource use / Resources / Resource utilisation / Healthcare utilization
- Disease
- Surgery type
- Conservative treatment / conservative care/watchful waiting
- Optional: Netherlands, Europe, UK, Germany

Pubmed:
“Costs” OR “Resource use” OR “Resources” OR “Resource utilization” OR “Healthcare utilization” AND

1. “<disease name>” OR “<surgery type>”
2. ”Conservative treatment” OR “Conservative care” OR “Watchful waiting”

Supplement S3. Impact of surgical delay for the Netherlands

Surgical procedure	Average number of surgeries per week	Costs associated with delay					Net monetary loss per week				
		% of surgeries delayed					% of surgeries delayed				
		10%	20%	30%	40%	50%	10%	20%	30%	40%	50%
Inguinal hernia repair	535.9	€0	€0	€0	€0	€0	€-2061	€-4122	€-6183	€-8244	€-10305
Laparoscopic sleeve gastrectomy	1.5	€5	€9	€14	€18	€23	€-13	€-25	€-38	€-51	€-63
laparoscopic Roux-and-Y gastric bypass	2.7	€8	€17	€25	€34	€42	€-21	€-42	€-63	€-84	€-105
Partial colectomy – Non-acute Crohn's disease	25.5	43	€86	€128	€171	€214	€-239	€-478	€-718	€-957	€-1196
Partial colectomy – Ulcerative colitis	9.8	€16	€31	€47	€62	€78	€-61	€-121	€-182	€-243	€-303
Sphincteroplasty	0.8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Total hip replacement	574.3	€553	€1106	€1660	€2213	€2766	€-6539	€-13078	€-19617	€-26156	€-32695
Total knee replacement	552.5	€532	€1065	€1597	€2129	€2661	€-5207	€-10415	€-15622	€-20830	€-26037
Total shoulder replacement	56.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Arthroscopic partial meniscectomy	406.8	€-65	€-131	€-196	€-262	€-327	€-731	€-1462	€-2193	€-2923	€-3654
Septoplasty	181.2	€-14	€-27	€-41	€-55	€-69	€-404	€-809	€-1213	€-1618	€-2022
Male sling procedure	2.6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tension-free vaginal tape procedure	66.5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Total per week*	2290	€1,077	€2,155	€3,232	€4,310	€5,388	-€15,764	-€31,529	-€47,293	-€63,058	-€78,823

*only including procedures with available cost and NML data
n.a. not available, NML: net monetary loss

Supplement S4. Waiting lists and net monetary losses of a large regional hospital in The Netherlands on 30 June 2020, 2019 and 2018.

Surgical procedure	2018				2019				2020			
	Patients waiting for surgery	**Waiting time**	**Costs associated with delay**	**Net monetary loss**	**Patients waiting for surgery**	**Waiting time**	**Costs associated with delay**	**Net monetary loss**	**Patients waiting for surgery**	**Waiting time**	**Costs associated with delay**	**Net monetary loss**
Inguinal hernia repair	25	4	€ 0	-€ 3,441	40	4	€ 0	-€ 6,851	36	12	€ 0	-€ 16,397
Laparoscopic sleeve gastrectomy	11	6	€ 1,943	-€ 5,316	3	5	€ 491	-€ 1,342	19	10	€ 5,682	-€ 15,543
laparoscopic Roux-and-Y gastric bypass	13	5	€ 2,046	-€ 5,095	7	6	€ 1,262	-€ 3,143	30	12	€ 10,798	-€ 26,890
Partial colectomy – Non-acute Crohn's disease	0	1	€ 0	€ 0	0	3	€ 0	€ 0	0	6	€ 0	€0
Partial colectomy – Ulcerative colitis	3	2	€ 100	-€ 387	1	2	€ 36	-€ 140	1	2	€ 34	-€ 131
Sphincteroplasty	0	3	n.a.	n.a.	1	6	n.a.	n.a.	1	0	n.a.	n.a.
Total hip replacement	57	7	€ 4,153	-€ 47,285	66	9	€ 6,016	-€ 68,489	202	17	€ 33,501	-€ 381,404
Total knee replacement	71	8	€ 5,836	-€ 55,216	71	11	€ 7,605	-€ 71,956	193	21	€ 39,770	-€ 376,299
Total shoulder replacement	4	6	n.a.	n.a.	3	8	n.a.	n.a.	11	14	n.a.	n.a.
Arthroscopic partial meniscectomy	17	4	-€ 112	-€ 1,227	19	5	-€ 139	-€ 1,527	15	13	-€ 317	-€ 3,475
Septoplasty	40	7	-€ 283	-€ 6,258	72	12	-€ 870	-€ 19,217	103	23	-€ 2,417	-€ 53,365
Male sling procedure	12	7	n.a.	n.a.	6	13	n.a.	n.a.	11	14	n.a.	n.a.
Tension-free vaginal tape procedure	4	14	n.a.	n.a.	2	32	n.a.	n.a.	2	17	n.a.	n.a.
Total	257		€ 13,682*	-€ 124,224*	291		€ 14,399*	-€ 172,664*	624		€ 87,049*	-€ 873,504*

* *only including procedures with available cost and NML data
n.a. not available, NML: net monetary loss

Development of a decision analytical framework to prioritize operating room capacity: Lessons learned from an empirical example on delayed elective surgeries during the COVID-19 pandemic in an hospital in the Netherlands

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2021-054110.R2
Article Type:	Original research
Date Submitted by the Author:	07-Mar-2022
Complete List of Authors:	Rovers, Maroeska; Radboudumc, Operating Rooms and Health Evidence Wijn, Stan; Radboudumc, Operating Rooms Grutters, Janneke; Radboudumc, Health Evidence & Operating Rooms Metsemakers, Sanne; Radboudumc, Operating Rooms Vermeulen, Robin; Radboudumc, Operating Rooms Van der Pennen, Ron; Tweesteden Hospital Location Saint Elisabeth Berden, Bart; Elisabeth-TweeSteden Ziekenhuis Gooszen, Hein; Radboudumc, Operating Rooms - Evidence Based Surgery Scholte, Mirre; Radboudumc, Operating Rooms Govers, Tim; Radboudumc, Operating rooms
Primary Subject Heading:	Surgery
Secondary Subject Heading:	Health economics, Evidence based practice, Health policy
Keywords:	COVID-19, HEALTH ECONOMICS, Organisation of health services < HEALTH SERVICES ADMINISTRATION & MANAGEMENT, SURGERY

Development of a decision analytical framework to prioritize operating room capacity: Lessons learned from an empirical example on delayed elective surgeries during the COVID-19 pandemic in an hospital in the Netherlands

Authors:

Maroeska M. Rovers[1,2], Stan R.W. Wijn[1], Janneke P. Grutters[1,2], Sanne Metsemakers[1], Robin Vermeulen[1], Ron van der Pennen[3], Bart Berden[3,4], Hein G. Gooszen[1], Mirre Scholte[1], Tim M. Govers[1]

Collaborators/acknowledgements:

Charlotte Michels[5,6], Milica Jevdjevic[7], Ilse Spenkelink[8], Niels van den Berkmortel[2], Casper Tax[9], Michiel Sedelaar[10], Camiel Rosman[11], Sebastiaan van der Goes[12], Tony van Tienen[13], Rudolph Poolman[14], Jelle Ruurda[15], Niek Stadhouder[16], Paul van Leest[3].

1. Department of Operating Rooms, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.
2. Department for Health Evidence, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.
3. Elisabeth Tweesteden Hospital, Tilburg, The Netherlands.
4. IQ healthcare, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands
5. Department of Urology, Rijnstate Hospital, Arnhem, The Netherlands.
6. Department of Operating Rooms, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.
7. Department of Dentistry-Quality and Safety of Oral Healthcare, Radboud University Medical Center, Radboud Institute for Health Sciences, Nijmegen, The Netherlands

8. Department of Radiology, Nuclear Medicine and Anatomy, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.
9. Department of General Surgery, Haaglanden Medical Centre, The Hague, The Netherlands.
10. Department of Urology, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.
11. Department of Surgery, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.
12. Department of Orthopedics, Radboud Institute for Health Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.
13. Orthopedic surgeon, Laurentius hospital Roermond
14. Department orthopedics, LUMC and OLVG, The Netherlands
15. Department of Surgery, University Medical Center Utrecht, The Netherlands
16. National Institute for Public Health and the Environment, PO Box 1, 3720 BA, Bilthoven, Netherlands

Correspondence to: M M Rovers, Radboud university medical center, Department of Operating Rooms, route 715, PO Box 9101, 6500 HB Nijmegen, the Netherlands

E: Maroeska.Rovers@radboudumc.nl, T: +31-622726370

Abstract

Objective: To develop a prioritization framework to support priority setting for elective surgeries after COVID-19 based on the impact on patient well-being and cost.

Design: We developed decision analytic models to estimate the consequences of delayed elective surgical procedures (e.g. total hip replacement, bariatric surgery or septoplasty)

Setting: The framework was applied to a large hospital in the Netherlands.

Outcome measures: impacts on quality of life and costs were taken into accound and combined to calculate net monetary losses per week delay, which quantifies the total loss for society expressed in monetary terms. Net monetary losses were weighted by operating times.

Results: We studied 13 common elective procedures from four specialities. Highest loss in quality of life due to delayed surgery was found for total hip replacement (utility loss of 0.27, i.e. 99 days lost in perfect health); the lowest for arthroscopic partial meniscectomy (utility loss of 0.05, i.e. 18 days lost in perfect health). Costs of surgical delay per patient were highest for bariatric surgery (€31/pp per week) and lowest for arthroscopic partial meniscectomy (-€2/pp per week). Weighted by OR time bariatric surgery provides most value (€1.19/pp per OR minute), arthroscopic partial meniscectomy provides the least value (€0.34/pp per OR minute). In a large hospital the net monetary loss due to prolonged waiting times was €700.840 after the first COVID-19 wave, an increase of 506% compared to the year before.

Conclusions: This surgical prioritization framework can be tailored to specific centres and countries to support priority setting for delayed elective operations during and after the COVID-19 pandemic, both in and between surgical disciplines. In the long-term, the framework can contribute to the efficient distribution of OR time and will therefore add to the discussion on appropriate use of health care budgets. The online framework can be accessed via: https://stanwijn.shinyapps.io/priORitize/

Strengths and limitations of this study

- Decision analytical modelling appears to be an efficient tool to compare the impact of delays in elective surgery due to the COVID-19 pandemic on patient quality of life and healthcare costs.
- The framework is available via an online tool that can easily be adapted according to local settings (e.g. regarding operation times, currencies) and new available evidence.
- Since high-quality data regarding the consequences of the delay of surgery on deterioration are lacking, this could not be included in our model.
- We used average data from literature rather than patient-level data, which could impact the applicability of our results to the individual patient.

Keywords

COVID-19, cancelled elective surgeries, OR capacity, OR prioritization, quality of life, cost, online framework

Word count abstract: 300

Word count main text (Background through Conclusions): 4194

Introduction

The extent to which the ongoing COVID-19 pandemic is disrupting global health, social welfare and the economy is unparalleled in modern history.[1] Due to this pandemic, hospitals, continue to have to drastically reduce elective surgeries. Current estimates suggest that worldwide more than 2 million operations per week have been cancelled during the first wave of this pandemic, and most of them comprise elective surgeries.[2,3] In the UK alone a reduction of 2.3 million performed elective surgerie is seen from march 2020 untill February 2022, increasing the number of patients waiting for elective surgery to 6 million.[4,5] It was also estimated that if countries increase their usual surgical volume by 20 percent after the pandemic, it would take about 45 weeks to clear the backlog due to the disruption.[2] With the current second wave and third waves, the number of delayed elective operations will only increase further. This not only affects the surgical disciplines, but also other related disciplines like gastroenterology, internal medicine, oncology, cardiology, neurology and general practitioners as they see the rise in time for referral of patients for surgery.

The word “elective” implies that the indication for surgery is not ‘acute and life-saving’ like in the case of life-threatening emergency. In most hospitals ‘acute’ cases have been scheduled without restriction during the pandemic. For the elective cases, it is likely that their suboptimal health status persisted during the extended waiting period, but there might also be patients where the delay to surgery may lead to deterioration of the disease and limit treatment options. However, it is also conceivable that their symptoms decrease during their extended waiting period, without affecting their personal life much, ultimately leading to cancelling of surgery.

The COVID-19 pandemic provides a unique opportunity to study these effects of delay of elective surgeries. Moreover, the discussion on healthcare interventions where scientific support for addition of value is limited or even lacking, has also been reopened. That is, healthcare professionals also have a responsibility to contribute to the affordability and accessibility of the healthcare system as a whole.[6,7] If healthcare can be made more sensible and qualitatively better, we can deliver more health care for less money. This requires not only a new mindset, but also reliable models and data to quantify the consequences of delay or even cancellation of surgery on patients and society. Models like ours will help to build an evidence-based framework which can be used to support priority setting for elective surgeries and subsequent optimisation of OR capacity. Therefore, our aim was to develop a framework to support priority setting for elective surgeries based on the impact on patient well-being and cost.

Methods

Decision analytic models were developed to estimate the consequences of delaying multiple elective surgical procedures, taking into account health impact and cost. The final framework, including all individual models, provides information on relevant factors that should be taken into account when prioritizing operations, i.e. loss in health-related quality of life (HRQoL), healthcare costs due to delay and the duration of the operation. We used data from available literature to calculate expected health loss and costs due to delay of surgery. The decision analytical models were developed in accordance with the modelling good research practices and described according to the CHEERS guidelines (Supplement S1).[8] Ethical approval was not required for this study as all data was obtained via literature searches.

Selected elective procedures

All procedures that could wait for at least 2 months after diagnosis according to the urgency categories of the Dutch Healthcare Authority during the early phase of the COVID-19 pandemic were considered for our model.[9] Clinical experts from multiple specialties were consulted to determine useful examples of clinical dilemmas in times of COVID-19. We decided to compare procedures within and between specialties to demonstrate how to prioritize within and between disciplines. The following elective procedures were included: general and gastrointestinal surgical procedures (inguinal hernia repair, laparoscopic sleeve gastrectomy (LSG), Roux-en-Y laparoscopic gastric bypass (LRYGB), partial colectomy for non-acute Crohn’s disease & ulcerative colitis, sphincteroplasty), urological/gynaecological procedures (male sling procedure, tension free vaginal tape procedure), orthopaedic procedures (total hip replacement, total knee replacement, total shoulder replacement, arthroscopic partial meniscectomy), and one otorhinolaryngological procedure (septoplasty) (Table 1).

Table 1. The 13 surgical procedures that are currently included in the framework.

Surgical procedure	Surgical specialty	Indication for surgery
Inguinal hernia repair	General surgery	Inguinal hernia
Laparoscopic sleeve gastrectomy	General surgery	Morbid obesity
laparoscopic Roux-and-Y gastric bypass	General surgery	Morbid obesity
Partial colectomy	Gastrointestinal surgery	Symptomatic Crohn's disease
Partial colectomy	Gastrointestinal surgery	Ulcerative colitis
Sphincteroplasty	Gastrointestinal surgery	Faecal incontinence
Total hip replacement	Orthopaedic surgery	Osteoarthritis of the hip
Total knee replacement	Orthopaedic surgery	Osteoarthritis of the knee
Total shoulder replacement	Orthopaedic surgery	Osteoarthritis of the shoulder
Arthroscopic partial meniscectomy	Orthopaedic surgery	Degenerative lesion of the meniscus
Septoplasty	Otorhinolaryngology	Nasal obstruction and/or deviated septum
Male sling procedure	Urology	Moderate stress urinary incontinence in men
Tension-free vaginal tape procedure	Urology	Stress urinary incontinence in women

Data acquisition and validation

For each case, input regarding cost and quality of life was derived from recent literature via semi-systematic literature searches in PubMed. Keywords included the disease of interest, the type of surgery, length of stay, costs (resource use / healthcare utilization) and quality of life. The search strategy can be found in Supplement S2. Ideally, a randomized controlled trial (RCT) or meta-analysis of multiple RCT's comparing surgery to watchful waiting or non-surgical care, was used to inform the model. If these were not available, alternative high-quality data sources, such as observational cohort studies or equivalent alternatives, were retrieved. If studies comparing surgery to watchful waiting or non-surgical care were not available, before and after surgical studies were used to estimate the effect of postponing surgery. The quality of the studies was assessed using a checklist in which we scored the validity of the operation times and utilities used. In addition, for each case study a clinical expert was consulted to ensure that all important aspects of the patient population, disease and surgery were captured. To validate our data, we also compared them with data from the Dutch National Institute for Public Health and the Environment (RIVM) that studied the consequences of delayed surgery for the Dutch government.[10]

Quality of life

Effectiveness was measured in terms of utility values, which reflects health-related quality of life on a 0-1 scale, with 0 representing death and 1 representing full health. Utility values were derived from the EQ-5D questionnaire.[11,12] When available, differences in utilities between surgery and watchful waiting were extracted at 6-12 months intervals to calculate the gain in utility which can be reached by performing the surgery. If a watchful waiting cohort was not available, the baseline utility (measured before surgery) of surgical patients was taken to calculate the gain in utility which can be reached by performing the surgery.

We assumed that gain in utility that can be reached by performing a surgery represents the loss in utility in case surgery is delayed. That is, if an operation that increases a patients utility with 0.2 is postponed for one year, we assume a total loss of utility of 0.2 over that year. Figure 1a shows how we calculated the impact of delayed surgery on the loss of quality of life (in utility values).

[*insert Figure 1*]

Costs

The extra health care expenditure due to waiting for surgery was determined by calculating the difference in healthcare expenditure before and after surgery (Figure 1b). Only costs from a healthcare perspective were included, e.g. extra visits to the hospital, general practitioner, physiotherapist. Costs of surgery itself were not included, as we assumed that all patients would receive surgery. To enable a comparison between procedures we extracted the resource use (e.g.

number of extra hospital visits) rather than the actual cost from literature. The resource use was multiplied by standard unit prices for each procedure, ensuring a similar calculation of costs across operations. When available, unit prices were derived from the Dutch guideline for costing research.[13] Otherwise, unit prices were obtained from hospital fees. We excluded medication costs since this was often not reported or the reporting lacked detailed information necessary for our model. Costs were calculated in Euros (€) and based on the 2019 price level.

Operating time

Operating time for all surgical procedures was extracted from literature to weigh the impact of surgery against the time needed to perform the surgery (see analysis). Operating time was considered to be the total time the patient was in the operating theatre, including anaesthesia and surgery (skin-to-skin) time, and was extracted from literature. To validate these data, we compared them with the empirical data provided by two hospitals. Furthermore, in the online available framework, the operating time can be adjusted to match operating times for a specific setting.

Analysis

We calculated the loss of quality of life (in utilities) and extra costs per week delay of surgery based on the obtained utility values and costs. Subsequently, we calculated the net monetary loss, which is defined as the total loss of waiting another week for surgery, expressed in monetary terms. The net monetary loss is calculated by multiplying the loss in quality of life due to waiting one week for surgery by a threshold value, and subsequently the extra costs of waiting another week for surgery are added. We used a threshold value of €20,000 per year of full health, as recommended for conditions with a relatively low burden of disease by the Dutch guidelines for cost-effectiveness (Figure 1c).[13] As an example, let’s assume a surgical procedure leads to a 0.2 gain in utility and a decrease in the patient’s healthcare expenses of €50 per week. Delaying this procedure for one week results in a net monetary loss of $\left(0.2 \times {}^{1}/_{52} \times €20.000\right) + €50 = €127$. The procedure with the highest net monetary loss therewith provides the most 'value' when prioritized. Subsequently, we also took into account the operating time since more patients can benefit from procedures with short operating times given a fixed OR capacity. For example, when a surgical procedure "X" can be performed twice in the timeframe of procedure "Y", procedure "Y" has to result in twice as much value to have a similar value in the same OR time (Figure 1d). Therefore, the net monetary loss per week was weighted for the operating time, resulting in the net monetary loss per week per OR minute.

Last, we calculated the impact of postponing these elective surgeries during one of the COVID-19 waves, assuming 30% delay in these 13 elective surgeries over a 3 month period as compared to the year before. We calculated the impact of postponing elective surgeries in total costs and total net monetary loss.

Empirical example

To illustrate how our framework works and can be used in clinical practice, we applied it on real world data from a large regional hospital in The Netherlands. Data used from this hospital comprise the actual numbers of patients waiting for each of the 13 included procedures on June 30 in 2020, 2019 and 2018 and the average waiting time for each procedure in these years. Based on these data we calculated the total net monetary loss after the first COVID-19 wave (June 30, 2020) as compared to 2019 and 2018. This was done by multiplying the number of patients that are waiting by the average waiting time and the net monetary loss for that procedure.

Interactive surgical prioritization framework

The decision-analytic models for the elective surgical procedures were wrapped in an interactive web-based framework developed to further stimulate engagement and discussion between the relevant stakeholders, i.e. surgical disciplines, anaesthesiology, other referring medical disciplines, and decision makers. By default, the interactive framework shows the results presented in this paper, but users of the framework can alter some of the parameters (e.g. the operation time) or select procedures relevant to their departments or strategy. In this way the framework can be used on different strategic levels, i.e. department level or hospital level (for decisions across departments). Furthermore, cost prices of the different resources and currencies can be altered to make the framework applicable for other countries. The framework was built using R (version 4.0.2, The R Foundation for Statistical Computing, Vienna, Austria) with shiny (version 1.5.0) and shinydashboard (version 0.7.1) packages.[14,15] The interactive framework is available via https://stanwijn.shinyapps.io/priORitize/

Patient and Public Involvement

There was no patient or public involvement in the study.

Results

Quality of life

The highest loss in quality of life due to delayed surgery was found for total hip replacement (utility of 0.27, i.e. 99 days lost in perfect health when waiting for a year), followed by total shoulder and knee replacement (utilities of 0.22 and 0.22, i.e. 80 days lost in perfect health when waiting for a year), respectively (Table 2). The lowest loss in quality of life was found for arthroscopic partial meniscectomy (utility of 0.05, i.e. 18 days lost in perfect health when waiting for a year), see also Figure 2a. For sphincteroplasty, the male sling procedure, and the tension-free vaginal tape procedure utility values were not available in literature.

Table 2. Overview of the data in the surgical prioritization framework.

Surgical procedure	Surgical specialty	Operating time (min)	Utility pre-surgery	Utility post-surgery	Δ Utility	Cost per week (€)	NML per week (€)	NML by operating time (€)	References Operating time	References Resource use	References Quality of life
Inguinal hernia repair	General surgery	54	0.78	0.88	0.1	€ 0	-€ 38	-€ 0.7	[16]	[17,18]	[19]
Laparoscopic sleeve gastrectomy	General surgery	71	0.73	0.87	0.14	€ 31	-€ 85	-€ 1.2	[20]	[21–25]	[26,27]
laparoscopic Roux-and-Y gastric bypass	General surgery	82	0.75	0.87	0.12	€ 31	-€ 77	-€ 0.9	[20]	[21–25]	[26,27]
Partial colectomy – Non-acute Crohn's disease	Gastrointestinal surgery	180	0.75	0.95	0.2	€ 17	-€ 94	-€ 0.5	[28]	[29–32]	[33–35]
Partial colectomy –	Gastrointestinal surgery	180	0.84	0.96	0.12	€ 16	-€ 62	-€ 0.3	[28]	[29–32]	[33–35]

Ulcerative colitis											
Sphincteroplasty	Gastrointestinal surgery	180	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	[36]	n.a.	n.a.
Total hip replacement	Orthopaedic surgery	150	0.52	0.79	0.27	€ 10	-€ 114	-€ 0.8	Expert opinion	[37,38]	[39–42]
Total knee replacement	Orthopaedic surgery	106	0.51	0.73	0.22	€ 10	-€ 95	-€ 0.9	[43]	[38,44]	[45]
Total shoulder replacement	Orthopaedic surgery	181	0.66	0.89	0.22	n.a.	n.a.	n.a.	[46,47]	[48]	[49]
Arthroscopic partial meniscectomy	Orthopaedic surgery	50	0.75	0.8	0.05	-€ 2	-€ 18	-€ 0.3	Expert opion	[50]	[50]
Septoplasty	Otorhinolaryngology	61	0.83	0.89	0.06	-€ 1	-€ 22	-€ 0.4	[51]	[52]	[52]
Male sling procedure	Urology	59	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	[53]	n.a.	n.a.
Tension-free vaginal tape procedure	Urology	56	0.78	n.a.	n.a.	n.a.	n.a.	n.a.	[54]	n.a.	[54]

Min: minutes, n.a.: not available, NML: net monetary loss.

[insert Figure 2]

Cost

Delay of both LSG and LRYGB bariatric surgery resulted in the highest costs (€31 pp per week), followed by partial colectomy for non-acute Crohn's disease (€17 pp per week), and ulcerative colitis (€16 pp per week). Delay of arthroscopic partial meniscectomy was found to result in the lowest costs (-€2 pp per week), see also Figure 2b. For sphincteroplasty, total shoulder replacement, male sling procedure, and tension-free vaginal tape procedure, no literature was available to determine the extra resource use due to waiting for surgery.

Net monetary loss

Combining the loss in quality of life and extra costs resulted in a calculation of the net monetary loss per week. Total hip replacement was found to result in the highest loss per week of delay (€114 per week per procedure), followed by total knee replacement (€95 per week per procedure), and partial colectomy for non-acute Crohn's disease (€94 per week per procedure). Arthroscopic partial meniscectomy appears to result in the lowest loss per week (€18 per week per procedure), see also Figure 2c. It should be noted that the net monetary loss could only be calculated for procedures for which we could find information regarding the quality of life and costs in the literature.

Net monetary loss weighted by operating time

When the OR time per procedure is taken into account, the net monetary loss per week per OR minute shows that LSG provides the most value (€1.2 per week per OR minute), followed by LRYGB (€0.9 per week per OR minute), and total knee replacement (€0.9 per week per OR minute). Arthroscopic partial meniscectomy seems to provide the least value (€0.3 per week per OR minute), see also Figure 2d.

Impact of surgical delay

For the 13 included elective surgeries, we conservatively estimated that 30% was delayed for 3 months as compared to the total number that was performed in the year before Covid-19 (i.e. 27,500 elective surgeries for the 13 included procedures). In total, a 30% delay in the 13 selected elective surgical procedures resulted in €0.3 million extra costs for the healthcare system and a total impact on both cost and quality of life of €3.6 million. The impact of a 10 to 50% surgical delay for each procedure can be found in Supplement S3.

Empirical example

The impact of the COVID-19 crisis was clearly visible in the surgical waiting times of a large regional hospital in The Netherlands (Supplement S4). After the first COVID-19 wave (i.e. on June 30, 2020), 624 patients were waiting for one of the 13 included procedures, while on the same day in 2019 and 2018, 291 and 257 patients were waiting. As a consequence, the total net monetary loss after the first wave was €873.504, while the total net monetary losses were €172.664 and €124.224 in 2019 and 2018. Compared to June 30, 2019 and 2018, the total net monetary after the first wave increased with 506% (€700.840) and with 703% (€749.280), respectively.

Discussion

We developed a surgical prioritization framework that provides information that can be used to set priorities in elective surgeries. For example, the highest loss in quality of life due to delayed surgery was found for total hip replacement (utility of 0.27, i.e. 99 days lost in perfect health when waiting for a year); the lowest for arthroscopic partial meniscectomy (utility of 0.05, i.e. 18 days lost in perfect health when waiting for a year). Costs of surgical delay were highest for LSG and LRYGB (€31/pp per week) and lowest for arthroscopic partial meniscectomy (-€2/pp per week). Total hip replacement and total knee replacement resulted in the highest net monetary losses per week (€114 and €95, respectively), while septoplasty and arthroscopic partial meniscectomy had a net monetary loss per week of €22 and €18, respectively. In case we assumed that 30% of the 13 included procedures were delayed over a 3 month period as compared to the total numbers of procedures performed a year earlier, the delay resulted in €0.3 million extra costs for the Dutch healthcare system and a total impact on both cost and quality of life (net monetary loss) of €3.6 million. Data from a large regional hospital in The Netherlands show that more than twice as many patients were waiting for one of the 13 modelled operative procedures after the first COVID-19 wave as compared to 2019 (624 versus 291 patients, respectively). Consequently, the extra net monetary loss caused by these waiting times was €700.840, which is an increase of 506% compared to 2019.

Several other models to study the effect of delayed surgery and to inform surgical recovery plans have been developed. Degeling et al. for example,[55] developed a model to estimate the impact of delayed cancer diagnosis and treatment on survival outcomes and healthcare costs based on a shift in the cancer disease stage at treatment initiation. They showed that a conservative 3-month delay in cancer diagnosis and treatment due to the COVID-19 pandemic, results in an excess health cost of $12 million in Australia over 5 years for the in 2020 diagnosed patients for 4 cancers. Gravesteijn et al.[56] also developed a model that supports prioritization of care. They, however, focused on semi-elective surgeries, including cardiothoracic, oncological and transplantation surgery, whereas we

focused on elective surgeries. Needless to say that cancer patients and patients awaiting organ transplantation have a completely different profile as far as prognosis of their disease on the one hand and burden of awaiting treatment, on the other, is concerned. Furthermore, they used the global burden of disease by the WHO to estimate the QALY for 1/3 of the surgeries, and for the other 2/3 they used estimates by an expert panel. Our quality of life data are based on literature data from comparative studies using validated quality of life measures, which is in agreement with the ISPOR recommendation to use health-utility data collected from patients.[57] Wang et al.[58] developed a framework to model surgical backlog recovery. In contrast to our model, they did not include quality of life assessment to guide prioritization of care. They used available resources and bed capacity that are adjustable to other contexts, aiding region-specific decision-making. The COVIDSurg Collaborative[2] and Brandman et al.[59] separately developed models to predict the size of the backlog and time needed to restore this backlog. Although these models are different from the present framework, combining both perspectives might result in a comprehensive context specific policy to clear the surgical backlog.

The major strength of our approach is that the data used from literature are completely transparent in the online framework, and that it can easily be adapted according to local settings (e.g. regarding operation times) and new available evidence. Our model was built with high-quality QoL- and cost data that were derived from randomised controlled trials or comparative studies. We had the unique opportunity to cross validate our results to a national study by the Dutch Institute for Public Health and the Environment and empirical data from a large local hospital.[10] The concordance appeared to be very high with more than 75% overlap. Furthermore, by calculating the net monetary losses per week weighed by OR minute we were able to make a comparison between procedures and surgical disciplines based on the surgery time. This provides new insights on how to allocate valuable surgery time when comparing these operations, to maximize value.

Some potential limitations should also be discussed. First, we used average data from literature rather than patient-level data, which could impact the applicability of our results to the individual patient. However, our goal was to develop a practical framework to support priority setting able to generalize and compare on department and surgery level instead. The model is therefore useful in general during the COVID-19 pandemic as well as for policy-making in striving for quality-driven healthcare.

Second, we did not yet take into account other related factors such as ICU or personnel capacity, the number of beds available, the risk of exposing patients to perioperative COVID-19 infection, or psychological consequences. This was outside the scope of this paper but can be added in a future model, and of course these factors can be taken into account in the individual trade-off.

Third, impact of waiting on medication costs (for example pain medication that patients need while waiting for surgery), could not be taken into account because they were either not reported in literature or not described in enough detail to be suitable for inclusion in the model. In order to be able to take medication costs into account, better reporting of cost data, i.e. categorization of cost data, in clinical studies is needed. Furthermore, it could be expected that some patients need extra home care or had a prolonged stay in a nursing home because they are waiting for surgery. These costs were not reported in literature and were therefore not included in the model. Consequently, the total cost presented are an underestimation of the real cost.

Fourth, besides impact on quality of life, delayed surgery may have a variety of consequences regarding the deterioration of the disease ranging from 'no harm' (varices, inguinal hernia) to 'complications' (easy or difficult to treat, medically or surgically: Crohn's disease, ulcerative colitis) to disease-related death. Currently, high-quality data regarding the consequences of the delay of surgery on deterioration are lacking and could therefore not be included in our model. Because of the elective nature of the included procedures, we believe that deterioration with high impact (like disease-related death) will be limited. However, if this COVID-19 pandemic will prove that delaying

the included procedures do lead to high impact deterioration it is necessary to include the consequences of delaying surgery, the model can be adapted accordingly.

Fifth, so far, we only modelled 13 elective surgical procedures whereas there are many more. Since we developed an online framework, new data can easily be added to inform future decision making, for example additional high quality data comparing surgery to watchful waiting or non-surgical care. Others can also provide us with relevant information on other procedures, which we will check on consistency and validity, before adding them to the online framework.

Sixth, for some procedures no data on quality of life or costs were available in literature. The fact that no relevant data were retrieved from literature for sphincteroplasty , male sling procedure, and tension-free vaginal tape procedure illustrates how difficult it is, and will be, to calculate the added value of these procedures. It renders this type of surgery 'vulnerable' in strategic discussions, but also stimulates groups active in this complex field to come up with data in support of continuing this type of operations. We are, however, aware of research projects that will follow the patients currently 'waiting' due to the backlog of the pandemic.[60] Hopefully, these projects will provide us with more accurate data, which are critical to obtain reliable estimates.

The ongoing pandemic is having a collateral damage effect on health care and the delivery of surgical care to millions of patients worldwide. This is an effect that most certainly will persist for years to come. It is to be expected that cancer and other acute surgery, if cancelled during the pandemic, will be prioritized in most settings, whereas the impact on other elective surgeries for benign conditions will be cumulative, adding to the existing waiting times. Governments and other policy makers will be requested to fund substantial increases in surgical volume to clear backlogs, and this framework may help them to prioritize on evidence regarding QoL and cost savings rather than on a mixture of numbers and expert opinion.

When addressing the backlog of postponed elective surgeries, it is tempting to start with surgeries that cause a high net monetary loss when delayed on the one hand and have large volumes on the

other. However, as we look at bariatric surgery, we see a discrepancy between population impact and net monetary loss per OR minute. Although bariatric surgery has one of the highest net monetary losses of all procedures described in this paper, it has the lowest impact on population level due to small volumes. Also, when resuming total knee and total hip replacement first, huge numbers of patients need to be operated taking a lot of valuable OR time, while for bariatric surgery only a small number of patients needs to be operated. Therefore, we would like to emphasize that objective measures are indispensable for fair and justifiable prioritization of surgeries, and that these choices are preferably based on the net monetary loss per OR minute. Such medical care prioritisation data may add to future discussions on “appropriate use” of health care budgets.

In conclusion, our online framework can be used in deciding how to address the postponed elective surgeries after the COVID-19 pandemic. Furthermore, the model will also be useful during possible future repeated waves of COVID-19 or in the long-term as it provides relevant information regarding an efficient distribution of OR time.

Figure legends

Figure 1: Overview of the methods used. 1a: Loss in quality of life (QoL) due to delayed or postponed surgery was calculated by extracting the QoL before surgery from the QoL after surgery and multiplying this with the duration of the delay (one week in our analyses). 1b: The costs (in €) associated with waiting for surgery were calculated by extracting the average costs after surgery from the average costs before surgery and multiplying this with the duration of the delay (one week in our analyses). 1c: The net monetary loss (monetary measure to calculate the total societal loss of delaying surgery) was calculated by multiplying the loss in QoL by the willingness to pay (€ 20,000) and adding the extra costs associated with waiting for surgery. The willingness to pay represents the amount of money society is willing to pay for one year in full health. 1d: Surgery associated net monetary loss per week divided by operating time. Relevant when trying to optimize the operating schedule. During a two hour surgery, also two operations of one hour could be performed. In other words, the two hour surgery needs to be associated with twice as much NML as the 1 hour surgeries to be as worthwhile to perform.

Figure 2: Overview of results. 2a: Loss in quality of life (QoL) due to delayed or postponed surgery expressed as a utility score. A utility reflects QoL on a 0 to 1 scale, with 0 representing death and 1 representing full health. 2b: Extra health care expenditure due to waiting for surgery. 2c: The net monetary loss combines QoL and costs due to waiting for surgery, it is therefore the total loss of waiting another week for surgery, expressed in monetary terms. 2d: Surgery associated net monetary loss per week devided by operating time (i.e. it reflects the total cost per week per OR minute).

Declarations

Competing interests

MR had financial support by means of a VICI grant from NWO (Dutch Research Council) for the submitted work, the other authors had no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work

Licence

Contributors and sources

Authors:

MR, SW, JG, HG, MS, and TG have contributed to the conception and design of the study. All authors have contributed to the final design of the paper. Modelling was performed by SW, SM, RV, MS, and TG. Model input and feedback was received from RvdP, BB, HG, and our collaborators (see below). MR, SW, MS and TG drafted the manuscript. The online framework was developed by SW. All authors have made contributions to the drafting and revising of the article. All authors have read, reviewed and approved the final version of the manuscript before submission.

Collaborators:

In adherence to the ICMJE guidelines, we would also like to acknowledge the contributions of our collaborators: CM, MJ, IS and NvdB helped with the modelling. Model input and feedback was received from CT, MS, CR, SvdG, TvT, RP, JR, and NS. All collaborators have read and approved the final version of the manuscript before submission.

Role of the funding source

The study was funded by NWO (Dutch Research Council), VICI-project Rovers, project number 91818617. The funder had no role in the study design; in the collection, analysis, and interpretation of data; in the writing of the report; and in the decision to submit the article for publication. All authors were independent from the funder. All authors had full access to all of the data and can take responsibility for the integrity of the data and the accuracy of the data analysis. There was no commercial involvement in the study.

Transparancy

The lead authors affirm that the manuscript is an honest, accurate, and transparent account of the study being reported; and that no important aspects of the study have been omitted.

Data availability statement

All data used in this study were derived from sources available in the public domain. For references please refer to Table 2 or the online tool: https://stanwijn.shinyapps.io/priORitize/

References

1. Søreide K, Hallet J, Matthews JB, Schnitzbauer AA, Line PD, Lai PBS, et al. Immediate and long-term impact of the COVID-19 pandemic on delivery of surgical services. Br. J. Surg. John Wiley and Sons Ltd; 2020. p. 1250–61.
2. Nepogodiev D, Omar OM, Glasbey JC, Li E, Simoes JFF, Abbott TEF, et al. Elective surgery cancellations due to the COVID-19 pandemic: global predictive modelling to inform surgical recovery plans. Br. J. Surg. 2020;107(11):1440–9.
3. Fowler AJ, Dobbs TD, Wan YI, Laloo R, Hui S, Nepogodiev D, et al. Resource requirements for reintroducing elective surgery during the COVID-19 pandemic: modelling study. Br. J. Surg. 2021;108(1):97–103.
4. Campbell D. The NHS elective recovery plan: how it aims to clear the surgery backlog. The Guardian. 2022;02–7.
5. Nepogodiev D, Abbott TE, Ademuyiwa AO, AlAmeer E, Bankhead-Kendall BK, Biccard BM, et al. Projecting COVID-19 disruption to elective surgery. Lancet. 2022;399(10321):233–4.
6. Brody H. Medicine's Ethical Responsibility for Health Care Reform — The Top Five List. N. Engl. J. Med. 2010;362(4):283–5.
7. Morden NE, Colla CH, Sequist TD, Rosenthal MB. Choosing Wisely — The Politics and Economics of Labeling Low-Value Services. N. Engl. J. Med. 2014;370(7):589–92.
8. Caro JJ, Briggs AH, Siebert U, Kuntz KM. Modeling Good Research Practices—Overview: A Report of the ISPOR-SMDM Modeling Good Research Practices Task Force-1. Value Heal. 2012;15(6):796–803.
9. Dutch Healthcare Authority (NZa). Urgentielijst medisch-specialistische zorg - Nederlandse Zorgautoriteit [Internet]. [cited 2021 Mar 18]. Available from: https://puc.overheid.nl/nza/doc/PUC_306624_22/1/
10. Giessen A van, Wit A de, Brink C van den, Degeling K, Deuning C, Eeuwijk J, et al. Impact of the first wave of COVID-19 on regular healthcare and health [Internet]. 2020 [cited 2021 Mar 18].

p. 158. Available from: https://www.rivm.nl/en/bibcite/reference/337271

11. Rabin R, De Charro F. EQ-5D: A measure of health status from the EuroQol Group. In: Annals of Medicine. Royal Society of Medicine Press Ltd; 2001. p. 337–43.

12. Versteegh M, M. Vermeulen K, M. A. A. Evers S, de Wit GA, Prenger R, A. Stolk E. Dutch Tariff for the Five-Level Version of EQ-5D. Value Heal. 2016;19(4):343–52.

13. Hakkaart-van Roijen L, van der Linden N, Bouwmans C, Kanters T, Swan Tan S. Kostenhandleiding: Methodologie van kostenonderzoek en referentieprijzen voor economische evaluaties in de gezondheidszorg [Internet]. Dutch Natl. Heal. Care Inst. 2016. p. 1–73. Available from: https://www.zorginstituutnederland.nl/over-ons/publicaties/publicatie/2016/02/29/richtlijn-voor-het-uitvoeren-van-economische-evaluaties-in-de-gezondheidszorg

14. Chang W, Cheng J, Allaire JJ, Xie Y MJ. shiny: Web Application Framework for R version 1.3.2 from CRAN [Internet]. Compr. R Arch. Netw. 2017 [cited 2021 Mar 26]. Available from: https://rdrr.io/cran/shiny/

15. Chang W, Ribeiro BB. Package “ShinyDashboard”: Create Dashboards with “Shiny” [Internet]. Comprehensive R Archive Network (CRAN); 2018 [cited 2021 Mar 26]. p. 27. Available from: https://cran.r-project.org/package=shinydashboard

16. Langeveld HR, van’t Riet M, Weidema WF, Stassen LPS, Steyerberg EW, Lange J, et al. Total Extraperitoneal Inguinal Hernia Repair Compared With Lichtenstein (the LEVEL-Trial). Ann. Surg. 2010;251(5):819–24.

17. Stroupe KT, Manheim LM, Luo P, Giobbie-Hurder A, Hynes DM, Jonasson O, et al. Tension-Free Repair Versus Watchful Waiting for Men with Asymptomatic or Minimally Symptomatic Inguinal Hernias: A Cost-Effectiveness Analysis. J. Am. Coll. Surg. 2006;203(4):458–68.

18. Fitzgibbons RJ, Giobbie-Hurder A, Gibbs JO, Dunlop DD, Reda DJ, McCarthy M, et al. Watchful Waiting vs Repair of Inguinal Hernia in Minimally Symptomatic Men. JAMA. 2006;295(3):285.

19. Chard J, Kuczawski M, Black N, van der Meulen J. Outcomes of elective surgery undertaken in

independent sector treatment centres and NHS providers in England: audit of patient outcomes in surgery. BMJ. 2011;343(oct19 1):d6404–d6404.

20. Dogan K, Kraaij L, Aarts EO, Koehestanie P, Hammink E, van Laarhoven CJHM, et al. Fast-Track Bariatric Surgery Improves Perioperative Care and Logistics Compared to Conventional Care. Obes. Surg. 2015;25(1):28–35.

21. Poelemeijer YQM, Liem RSL, Nienhuijs SW. A Dutch Nationwide Bariatric Quality Registry: DATO. Obes. Surg. 2018;28(6):1602–10.

22. Espallardo O, Busutil R, Torres A, Zozaya N, Villoro R, Hidalgo-Vega Á. The Impact of Severe Obesity on Healthcare Resource Utilisation in Spain. Obes. Surg. 2017;27(8):2058–66.

23. Backes CF, Lopes E, Tetelbom A, Heineck I. Medication and nutritional supplement use before and after bariatric surgery. Sao Paulo Med. J. 2016;134(6):491–500.

24. Khan SS, Ning H, Wilkins JT, Allen N, Carnethon M, Berry JD, et al. Association of Body Mass Index With Lifetime Risk of Cardiovascular Disease and Compression of Morbidity. JAMA Cardiol. 2018;3(4):280.

25. Segal JB, Clark JM, Shore AD, Dominici F, Magnuson T, Richards TM, et al. Prompt Reduction in Use of Medications for Comorbid Conditions After Bariatric Surgery. Obes. Surg. 2009;19(12):1646–56.

26. Sendi P, Brunotte R, Potoczna N, Branson R, Horber FF. Health-Related Quality of Life in Patients with Class II and Class III Obesity. Obes. Surg. 2005;15(7):1070–6.

27. Biter LU, van Buuren MMA, Mannaerts GHH, Apers JA, Dunkelgrün M, Vijgen GHEJ. Quality of Life 1 Year After Laparoscopic Sleeve Gastrectomy Versus Laparoscopic Roux-en-Y Gastric Bypass: a Randomized Controlled Trial Focusing on Gastroesophageal Reflux Disease. Obes. Surg. 2017;27(10):2557–65.

28. Harrison OJ, Smart NJ, White P, Brigic A, Carlisle ER, Allison AS, et al. Operative Time and Outcome of Enhanced Recovery After Surgery After Laparoscopic Colorectal Surgery. JSLS J. Soc. Laparoendosc. Surg. 2014;18(2):265–72.

29. Rubin GP, Hungin APS, Kelly PJ, Ling J. Inflammatory bowel disease: epidemiology and management in an English general practice population. Aliment. Pharmacol. Ther. 2000;14(12):1553–9.

30. Miehsler W, Weichselberger M, Öfferlbauer-Ernst A, Dejaco C, Reinisch W, Vogelsang H, et al. Which patients with IBD need psychological interventions? A controlled study. Inflamm. Bowel Dis. 2008;14(9):1273–80.

31. Thia KT, Sandborn WJ, Harmsen WS, Zinsmeister AR, Loftus E V. Risk Factors Associated With Progression to Intestinal Complications of Crohn's Disease in a Population-Based Cohort. Gastroenterology. 2010;139(4):1147–55.

32. Hsu Y-C, Wu T-C, Lo Y-C, Wang L-S. Gastrointestinal complications and extraintestinal manifestations of inflammatory bowel disease in Taiwan: A population-based study. J. Chinese Med. Assoc. 2017;80(2):56–62.

33. Stark RG, Reitmeir P, Leidl R, König H-H. Validity, reliability, and responsiveness of the EQ-5D in inflammatory bowel disease in Germany. Inflamm. Bowel Dis. 2010;16(1):42–51.

34. Huppertz-Hauss G, Høivik ML, Langholz E, Odes S, Småstuen M, Stockbrugger R, et al. Health-related Quality of Life in Inflammatory Bowel Disease in a European-wide Population-based Cohort 10 Years After Diagnosis. Inflamm. Bowel Dis. 2015;21(2):337–44.

35. Penner RM, Tandon P. Management of Crohn disease after surgical resection - UpToDate [Internet]. Up To Date. 2017 [cited 2021 Apr 8]. Available from: https://www.uptodate.com/contents/management-of-crohn-disease-after-surgical-resection?search=crohn disease surgical treatment&topicRef=86198&source=see_link%0Ahttps://www.uptodate.com/contents/management-of-crohn-disease-after-surgical-resection?source=h

36. Ratto C, Litta F, Donisi L, Parello A. Fistulotomy or fistulectomy and primary sphincteroplasty for anal fistula (FIPS): a systematic review. Tech. Coloproctol. 2015;19(7):391–400.

37. Fordham R, Skinner J, Wang X, Nolan J. The economic benefit of hip replacement: a 5-year

follow-up of costs and outcomes in the Exeter Primary Outcomes Study. BMJ Open. 2012;2(3):e000752.

38. Bozic KJ, Stacey B, Berger A, Sadosky A, Oster G. Resource utilization and costs before and after total joint arthroplasty. BMC Health Serv. Res. 2012;12(1):73.

39. Johnson EC, Horwood J, Gooberman-Hill R. Conceptualising time before surgery: The experience of patients waiting for hip replacement. Soc. Sci. Med. 2014;116:126–33.

40. Konopka JF, Lee Y, Su EP, McLawhorn AS. Quality-Adjusted Life Years After Hip and Knee Arthroplasty. JBJS Open Access. 2018;3(3):e0007.

41. Rolfson O, Dahlberg LE, Nilsson J-å., Malchau H, Garellick G. Variables determining outcome in total hip replacement surgery. J. Bone Joint Surg. Br. 2009;91-B(2):157–61.

42. Gordon M, Greene M, Frumento P, Rolfson O, Garellick G, Stark A. Age- and health-related quality of life after total hip replacement. Acta Orthop. 2014;85(3):244–9.

43. Ravi B, Jenkinson R, O'Heireamhoin S, Austin PC, Aktar S, Leroux TS, et al. Surgical duration is associated with an increased risk of periprosthetic infection following total knee arthroplasty: A population-based retrospective cohort study. EClinicalMedicine. 2019;16:74–80.

44. Picard F, Deakin A, Balasubramanian N, Gregori A. Minimally invasive total knee replacement: techniques and results. Eur. J. Orthop. Surg. Traumatol. 2018;28(5):781–91.

45. Jansson K-ÅÅ, Granath F. Health-related quality of life (EQ-5D) before and after orthopedic surgery. Acta Orthop. 2011;82(1):82–9.

46. Dunn JC, Lanzi J, Kusnezov N, Bader J, Waterman BR, Belmont PJ. Predictors of length of stay after elective total shoulder arthroplasty in the United States. J. Shoulder Elb. Surg. 2015;24(5):754–9.

47. Padegimas EM, Hendy BA, Lawrence C, Devasagayaraj R, Zmistowski BM, Abboud JA, et al. An analysis of surgical and nonsurgical operating room times in high-volume shoulder arthroplasty. J. Shoulder Elb. Surg. 2017;26(6):1058–63.

48. Grobet CE, Glanzmann MC, Eichler K, Rickenbacher D, Meier F, Brunner B, et al. Cost-utility

analysis of total shoulder arthroplasty: A prospective health economic study using real-world data. J. Shoulder Elb. Surg. 2021;1.

49. Evans J, Dattani R, Ramasamy V, Patel V. Responsiveness of the EQ-5D-3L in elective shoulder surgery: Does it adequately represent patient experience? J. Orthop. Surg. 2018;26(2).

50. Van De Graaf VA, van Dongen JM, Willigenburg NW, Noorduyn JCAA, Butter IK, De Gast A, et al. How do the costs of physical therapy and arthroscopic partial meniscectomy compare? A trial-based economic evaluation of two treatments in patients with meniscal tears alongside the ESCAPE study. Br. J. Sports Med. 2020;54(9):538–45.

51. Menezes AS, Guimarães JR, Breda M, Vieira V, Dias L. Septal and turbinate surgery: is overnight essential? Eur. Arch. Oto-Rhino-Laryngology. 2018;275(1):131–8.

52. van Egmond MMHT, Rovers MM, Hannink G, Hendriks CTM, van Heerbeek N. Septoplasty with or without concurrent turbinate surgery versus non-surgical management for nasal obstruction in adults with a deviated septum: a pragmatic, randomised controlled trial. Lancet. 2019;394(10195):314–21.

53. Leruth J, Waltregny D, de Leval J. The Inside-Out Transobturator Male Sling for the Surgical Treatment of Stress Urinary Incontinence After Radical Prostatectomy: Midterm Results of a Single-Center Prospective Study. Eur. Urol. 2012;61(3):608–15.

54. Manca A, Sculpher MJ, Ward K, Hilton P. A cost-utility analysis of tension-free vaginal tape versus colposuspension for primary urodynamic stress incontinence. BJOG. 2003;110(3):255–62.

55. Degeling K, Baxter NN, Emery J, Jenkins MA, Franchini F, Gibbs P, et al. An inverse stage-shift model to estimate the excess mortality and health economic impact of delayed access to cancer services due to the COVID-19 pandemic. Asia. Pac. J. Clin. Oncol. 2021;ajco.13505.

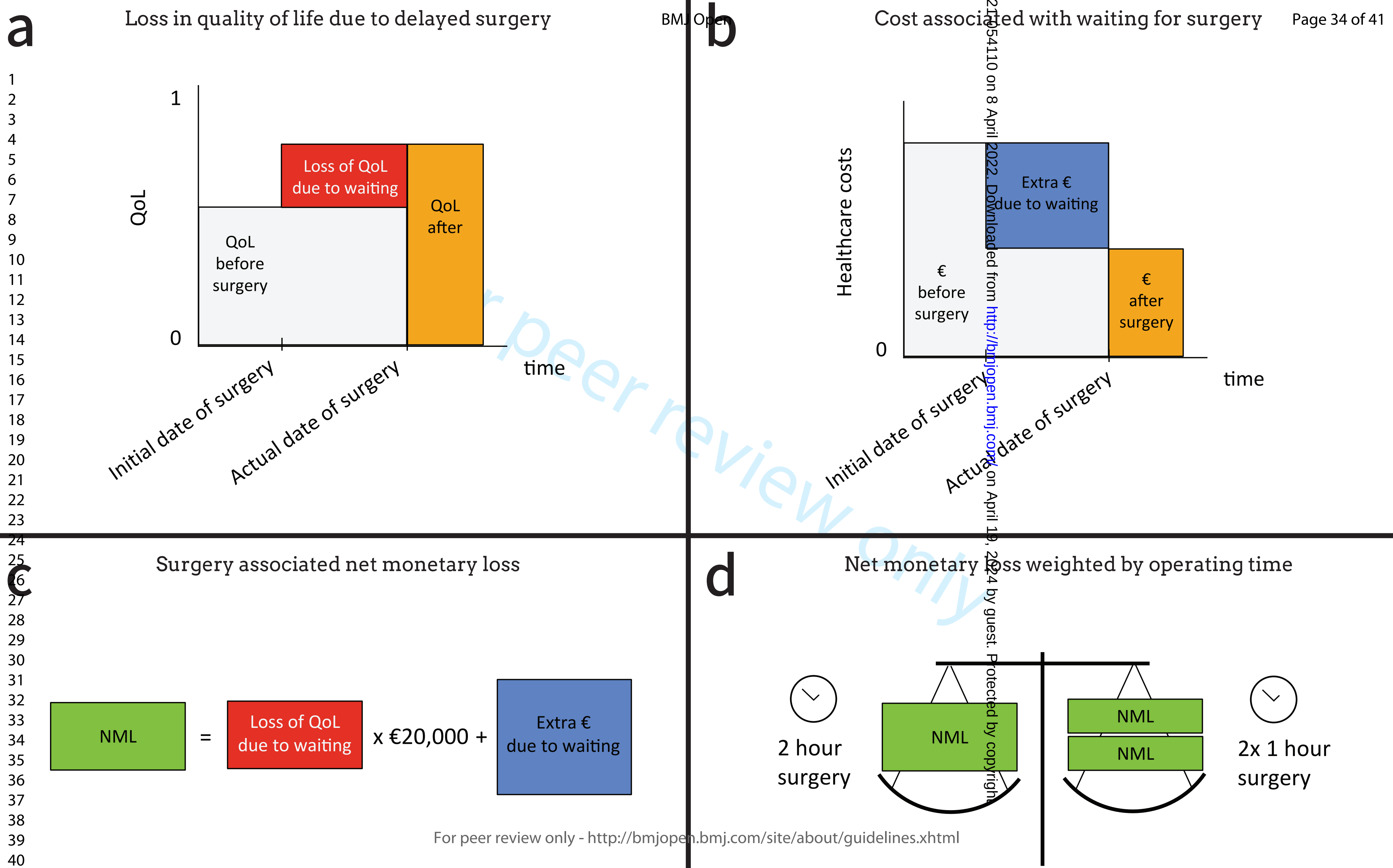
56. Gravesteijn B, Krijkamp E, Busschbach J, Geleijnse G, Helmrich IR, Bruinsma S, et al. Minimizing Population Health Loss in Times of Scarce Surgical Capacity During the Coronavirus Disease 2019 Crisis and Beyond: A Modeling Study. Value Heal. 2021;1–10.

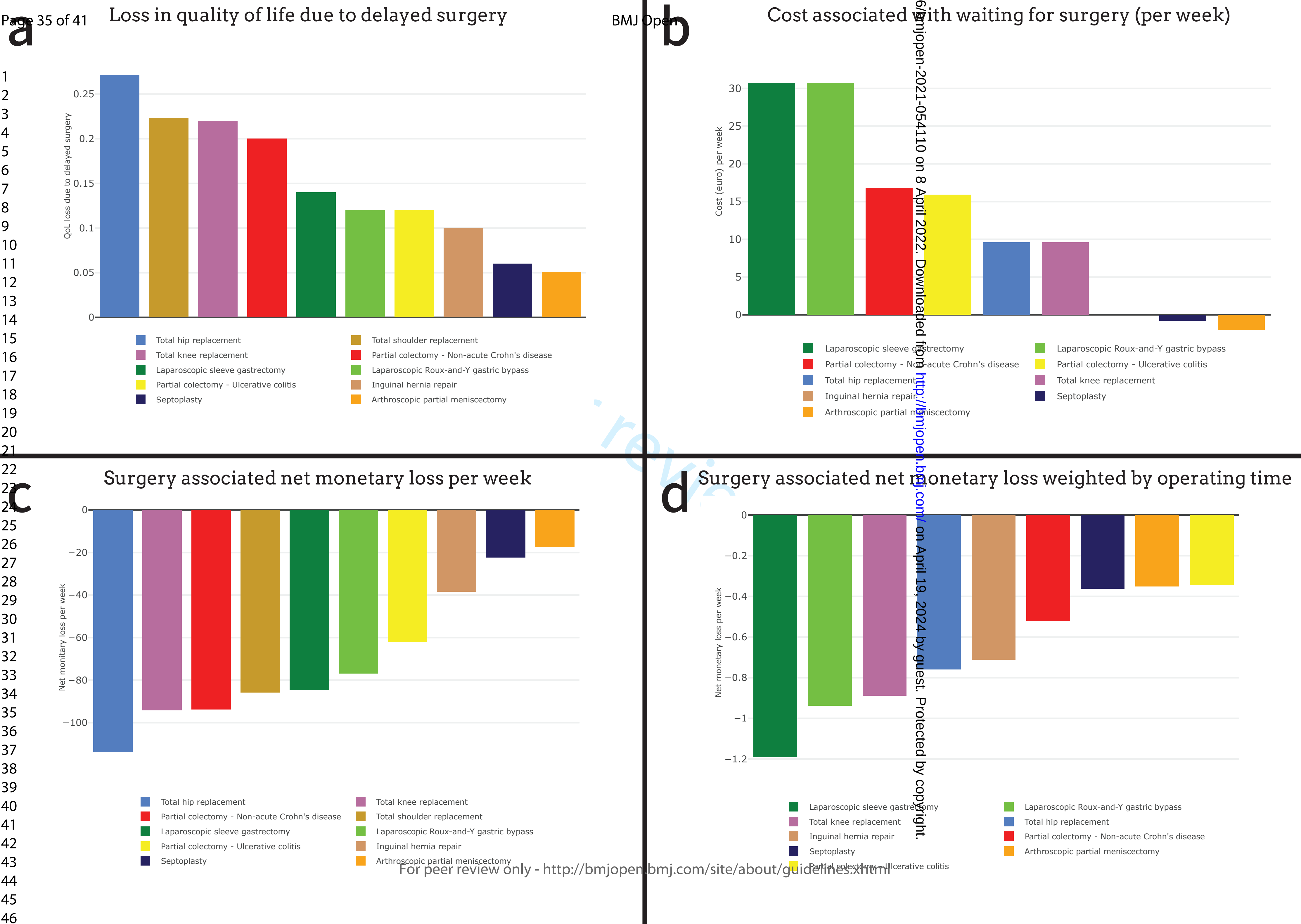
57. Brazier J, Ara R, Azzabi I, Busschbach J, Chevrou-Séverac H, Crawford B, et al. Identification, Review, and Use of Health State Utilities in Cost-Effectiveness Models: An ISPOR Good Practices for Outcomes Research Task Force Report. Value Heal. 2019;22(3):267–75.

58. Wang J, Vahid S, Eberg M, Milroy S, Milkovich J, Wright FC, et al. Clearing the surgical backlog caused by COVID-19 in Ontario: A time series modelling study. CMAJ. 2020;192(44):E1347–56.

59. Brandman DM, Leck E, Christie S. Modelling the backlog of COVID-19 cases for a surgical group. Can. J. Surg. 2020;63(5):E391–2.

60. TRACE II: Patiëntuitkomsten na uitgestelde electieve operaties tijdens de COVID-19 pandemie - ZonMw [Internet]. [cited 2021 Mar 18]. Available from: https://www.zonmw.nl/nl/over-zonmw/coronavirus/programmas/project-detail/covid-19-programma/trace-ii-outcome-in-patients-undergoing-postponed-elective-surgery-during-the-covid-19-pandemic/


a
Loss in quality of life due to delayed surgery
1
0
QoL
Loss of QoL due to waiting
QoL after
QoL before surgery
time
Initial date of surgery
Actual date of surgery
b
Cost associated with waiting for surgery
Healthcare costs
0
Extra € due to waiting
€ before surgery
€ after surgery
time
Initial date of surgery
Actual date of surgery
c
Surgery associated net monetary loss
NML
=
Loss of QoL due to waiting
x €20,000 +
Extra € due to waiting
d
Net monetary loss weighted by operating time
2 hour surgery
NML
NML
NML
2x 1 hour surgery


a
Loss in quality of life due to delayed surgery
QoL loss due to delayed surgery
0.25
0.2
0.15
0.1
0.05
0
Total hip replacement
Total shoulder replacement
Total knee replacement
Partial colectomy - Non-acute Crohn's disease
Laparoscopic sleeve gastrectomy
Laparoscopic Roux-and-Y gastric bypass
Partial colectomy - Ulcerative colitis
Inguinal hernia repair
Septoplasty
Arthroscopic partial meniscectomy
b
Cost associated with waiting for surgery (per week)
Cost (euro) per week
30
25
20
15
10
5
0
Laparoscopic sleeve gastrectomy
Laparoscopic Roux-and-Y gastric bypass
Partial colectomy - Non-acute Crohn's disease
Partial colectomy - Ulcerative colitis
Total hip replacement
Total knee replacement
Inguinal hernia repair
Septoplasty
Arthroscopic partial meniscectomy
c
Surgery associated net monetary loss per week
Net monitary loss per week
0
−20
−40
−60
−80
−100
Total hip replacement
Total knee replacement
Partial colectomy - Non-acute Crohn's disease
Total shoulder replacement
Laparoscopic sleeve gastrectomy
Laparoscopic Roux-and-Y gastric bypass
Partial colectomy - Ulcerative colitis
Inguinal hernia repair
Septoplasty
Arthroscopic partial meniscectomy
d
Surgery associated net monetary loss weighted by operating time
Net monetary loss per week
0
−0.2
−0.4
−0.6
−0.8
−1
−1.2
Laparoscopic sleeve gastrectomy
Laparoscopic Roux-and-Y gastric bypass
Total knee replacement
Total hip replacement
Inguinal hernia repair
Partial colectomy - Non-acute Crohn's disease
Septoplasty
Arthroscopic partial meniscectomy
Partial colectomy - Ulcerative colitis

CHEERS 2022 Checklist

Title			
Title	1	Identify the study as an economic evaluation and specify the interventions being compared.	Title, Page 1, line 1 - 3. The study is identified as decision analytical modelling study
Abstract			
Abstract	2	Provide a structured summary that highlights context, key methods, results, and alternative analyses.	Abstract, Page 3, line 39 - 61. The abstract is structured and includes objective, design, setting, outcome measures, results and conclusions
Introduction			
Background and objectives	3	Give the context for the study, the study question, and its practical relevance for decision making in policy or practice.	Introduction, Page 5, line 83 - 113.
Methods			
Health economic analysis plan	**4**	**Indicate whether a health economic analysis plan was developed and where available.**	**n.a.**
Study population	5	Describe characteristics of the study population (such as age range, demographics, socioeconomic, or clinical characteristics).	Methods, Selected elective procedures paragraph, Page 7 - 8, line 126-141.
Setting and location	6	Provide relevant contextual information that may influence findings.	Methods, Selected elective procedures and empirical example paragraph, Page 7 - 8, line 126 - 141 and page 11, line 216 - 223.
Comparators	7	Describe the interventions or strategies being compared and why chosen.	Methods, Selected elective procedures paragraph, Page 7 - 8, line 126-141.
Perspective	8	State the perspective(s) adopted by the study and why chosen.	Methods, Costs paragraph, Page 9 - 10, line 175 - 186.

(continued)

Time horizon	9	State the time horizon for the study and why appropriate.	Methods, Costs paragraph, Page 9 - 10, line 175 - 186.
Discount rate	10	Report the discount rate(s) and reason chosen.	n.a
Selection of outcomes	11	Describe what outcomes were used as the measure(s) of benefit(s) and harm(s).	Methods, Quality of life, costs and analysis paragraphs, Page 9 - 11, line 160 - 186 and line 194 - 215.
Measurement of outcomes	12	Describe how outcomes used to capture benefit(s) and harm(s) were measured.	Methods, Quality of life, costs and analysis paragraphs, Page 9 - 11, line 160 - 186 and line 194 - 215.
Valuation of outcomes	13	Describe the population and methods used to measure and value outcomes.	Methods, Data acquisition and validation paragraph and appendices, Page 8, line 144 - 158.
Measurement and valuation of resources and costs	14	Describe how costs were valued.	Methods, Costs paragraph, Page 9 - 10, line 175 - 186.
Currency, price date, and conversion	15	Report the dates of the estimated resource quantities and unit costs, plus the currency and year of conversion.	Methods, Costs paragraph and online tool, Page 9 - 12, line 175 - 186 and line 224 - 236.
Rationale and description of model	16	If modelling is used, describe in detail and why used. Report if the model is publicly available and where it can be accessed.	Methods, Entire methods section, Page 7, line 115 - 124.
Analytics and assumptions	17	Describe any methods for analysing or statistically transforming data, any extrapolation methods, and approaches for validating any model used.	Methods, Entire methods section, Page 10 - 11, line 194 - 215.
Characterising heterogeneity	18	Describe any methods used for estimating how the results of the study vary for subgroups.	n.a

(continued)

Characterising distributional effects	19	Describe how impacts are distributed across different individuals or adjustments made to reflect priority populations.	n.a
Characterising uncertainty	20	Describe methods to characterise any sources of uncertainty in the analysis.	n.a
Approach to engagement with patients and others affected by the study	21	Describe any approaches to engage patients or service recipients, the general public, communities, or stakeholders (such as clinicians or payers) in the design of the study.	Methods, Patient and Public Involvement, Page 12, line 237 - 238
Results			
Study parameters	22	Report all analytic inputs (such as values, ranges, references) including uncertainty or distributional assumptions.	Results, Entire results section, Page 13 - 16, line 239 - 289
Summary of main results	23	Report the mean values for the main categories of costs and outcomes of interest and summarise them in the most appropriate overall measure.	Results, First 4 paragraphs of the results section, Page 13 - 16, line 239 - 274
Effect of uncertainty	24	Describe how uncertainty about analytic judgments, inputs, or projections affect findings. Report the effect of choice of discount rate and time horizon, if applicable.	n.a
Effect of engagement with patients and others affected by the study	25	Report on any difference patient/service recipient, general public, community, or stakeholder involvement made to the approach or findings of the study	n.a
Discussion			

(continued)

Study findings, limitations, generalisability, and current knowledge	26	Report key findings, limitations, ethical or equity considerations not captured, and how these could affect patients, policy, or practice.	Discussion, Entire discussion section, Page 17 - 21, line 290 - 400
Other relevant information			
Source of funding	27	Describe how the study was funded and any role of the funder in the identification, design, conduct, and reporting of the analysis	Declarations, Role of the funding source statement, Page 24, line 457 - 463
Conflicts of interest	28	Report authors conflicts of interest according to journal or International Committee of Medical Journal Editors requirements.	Declarations, Competing interests statement, Page 23, line 433 - 438

From: Husereau D, Drummond M, Augustovski F, et al. Consolidated Health Economic Evaluation Reporting Standards 2022 (CHEERS 2022) Explanation and Elaboration: A Report of the ISPOR CHEERS II Good Practices Task Force. Value Health 2022;25. doi:10.1016/j.jval.2021.10.008

Supplement S2: Search strategy for model data

OR Time / Length of stay after OR

- Disease
- Surgery type
- Length of stay / hospital stay
- Optional: Netherlands, Europe, UK, Germany

Pubmed:

1. “<Disease>” AND “<Surgery type>” FILTER RCT
2. “<Disease>” AND “<Surgery type>” AND (“length of stay” OR “hospital stay”)
3. Patient information folder

Utility scores

- Utility score / EQ5D /Quality of Life
- Disease
- Surgery type
- Conservative treatment / conservative care / watchful waiting
- Optional: Netherlands, Europe, UK, Germany

Pubmed:

“Utility score” OR “EQ5D” OR “Quality of Life” AND

1. “<disease name>” OR “<surgery type>”
2. ”Conservative treatment” OR “Conservative care” OR “Watchful waiting”

Costing data

- Costs / Resource use / Resources / Resource utilisation / Healthcare utilization
- Disease
- Surgery type
- Conservative treatment / conservative care/watchful waiting
- Optional: Netherlands, Europe, UK, Germany

Pubmed:

“Costs” OR “Resource use” OR “Resources” OR “Resource utilization” OR “Healthcare utilization” AND

1. “<disease name>” OR “<surgery type>”
2. ”Conservative treatment” OR “Conservative care” OR “Watchful waiting”

Supplement S3. Impact of surgical delay for the Netherlands

Surgical procedure	**Average number of surgeries per week**	**Costs associated with delay**					**Net monetary loss per week**				
		% of surgeries delayed					% of surgeries delayed				
		10%	20%	30%	40%	50%	10%	20%	30%	40%	50%
Inguinal hernia repair	535.9	€0	€0	€0	€0	€0	€-2061	€-4122	€-6183	€-8244	€-10305
Laparoscopic sleeve gastrectomy	1.5	€5	€9	€14	€18	€23	€-13	€-25	€-38	€-51	€-63
laparoscopic Roux-and-Y gastric bypass	2.7	€8	€17	€25	€34	€42	€-21	€-42	€-63	€-84	€-105
Partial colectomy – Non-acute Crohn's disease	25.5	43	€86	€128	€171	€214	€-239	€-478	€-718	€-957	€-1196
Partial colectomy – Ulcerative colitis	9.8	€16	€31	€47	€62	€78	€-61	€-121	€-182	€-243	€-303
Sphincteroplasty	0.8	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Total hip replacement	574.3	€553	€1106	€1660	€2213	€2766	€-6539	€-13078	€-19617	€-26156	€-32695
Total knee replacement	552.5	€532	€1065	€1597	€2129	€2661	€-5207	€-10415	€-15622	€-20830	€-26037
Total shoulder replacement	56.9	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Arthroscopic partial meniscectomy	406.8	€-65	€-131	€-196	€-262	€-327	€-731	€-1462	€-2193	€-2923	€-3654
Septoplasty	181.2	€-14	€-27	€-41	€-55	€-69	€-404	€-809	€-1213	€-1618	€-2022
Male sling procedure	2.6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Tension-free vaginal tape procedure	66.5	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Total per week*	2290	€1,077	€2,155	€3,232	€4,310	€5,388	-€15,764	-€31,529	-€47,293	-€63,058	-€78,823

*only including procedures with available cost and NML data
n.a. not available, NML: net monetary loss

Supplement S4. Waiting lists and net monetary losses of a large regional hospital in The Netherlands on 30 June 2020, 2019 and 2018.

Surgical procedure	2018				2019				2020			
	Patients waiting for surgery	Waiting time	Costs associated with delay	Net monetary loss	Patients waiting for surgery	Waiting time	Costs associated with delay	Net monetary loss	Patients waiting for surgery	Waiting time	Costs associated with delay	Net monetary loss
Inguinal hernia repair	25	4	€ 0	-€ 3,441	40	4	€ 0	-€ 6,851	36	12	€ 0	-€ 16,397
Laparoscopic sleeve gastrectomy	11	6	€ 1,943	-€ 5,316	3	5	€ 491	-€ 1,342	19	10	€ 5,682	-€ 15,543
laparoscopic Roux-and-Y gastric bypass	13	5	€ 2,046	-€ 5,095	7	6	€ 1,262	-€ 3,143	30	12	€ 10,798	-€ 26,890
Partial colectomy – Non-acute Crohn's disease	0	1	€ 0	€ 0	0	3	€ 0	€ 0	0	6	€ 0	€0
Partial colectomy – Ulcerative colitis	3	2	€ 100	-€ 387	1	2	€ 36	-€ 140	1	2	€ 34	-€ 131
Sphincteroplasty	0	3	n.a.	n.a.	1	6	n.a.	n.a.	1	0	n.a.	n.a.
Total hip replacement	57	7	€ 4,153	-€ 47,285	66	9	€ 6,016	-€ 68,489	202	17	€ 33,501	-€ 381,404
Total knee replacement	71	8	€ 5,836	-€ 55,216	71	11	€ 7,605	-€ 71,956	193	21	€ 39,770	-€ 376,299
Total shoulder replacement	4	6	n.a.	n.a.	3	8	n.a.	n.a.	11	14	n.a.	n.a.
Arthroscopic partial meniscectomy	17	4	-€ 112	-€ 1,227	19	5	-€ 139	-€ 1,527	15	13	-€ 317	-€ 3,475
Septoplasty	40	7	-€ 283	-€ 6,258	72	12	-€ 870	-€ 19,217	103	23	-€ 2,417	-€ 53,365
Male sling procedure	12	7	n.a.	n.a.	6	13	n.a.	n.a.	11	14	n.a.	n.a.
Tension-free vaginal tape procedure	4	14	n.a.	n.a.	2	32	n.a.	n.a.	2	17	n.a.	n.a.
Total	257		€ 13,682*	-€ 124,224*	291		€ 14,399*	-€ 172,664*	624		€ 87,049*	-€ 873,504*

* *only including procedures with available cost and NML data
n.a. not available, NML: net monetary loss