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

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3 **1 Lessons learned from cancelled elective surgeries during the COVID-19**
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6 **2 pandemic: development of a framework to prioritize OR capacity**
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10 4 Authors:

11 5 *Maroeska M. Rovers^{1,2}, Stan R.W. Wijn¹, Janneke P. Grutters^{1,2}, Sanne Metsemakers¹, Robin*
12
13 6 *Vermeulen¹, Ron van der Pennen³, Bart Berden^{3,4}, Hein G. Gooszen¹, Mirre Scholte¹, Tim M. Govers¹*
14
15
16
17
18
19

20 7

21 8 Collaborators/acknowledgements:

22 9 *Charlotte Michels^{5,6}, Milica Jevdjevic⁷, Ilse Spenkelink⁸, Niels van den Berkmortel², Casper Tax⁹,*
23
24 10 *Michiel Sedelaar¹⁰, Camiel Rosman¹¹, Sebastiaan van der Goes¹², Tony van Tienen¹³, Rudolph*
25
26 11 *Poolman¹⁴, Jelle Ruurda¹⁵, Niek Stadhouders¹⁶, Paul van Leest³.*
27
28
29

30 12

- 31 1. Department of Operating Rooms, Radboud Institute for Health Sciences, Radboud University
32 Medical Center, Nijmegen, The Netherlands.
- 33 2. Department for Health Evidence, Radboud Institute for Health Sciences, Radboud University
34 Medical Center, Nijmegen, The Netherlands.
- 35 3. Elisabeth Tweesteden Hospital, Tilburg, The Netherlands.
- 36 4. IQ healthcare, Radboud Institute for Health Sciences, Radboud University Medical Center,
37 Nijmegen, The Netherlands
- 38 5. Department of Urology, Rijnstate Hospital, Arnhem, The Netherlands.
- 39 6. Department of Operating Rooms, Radboud Institute for Health Sciences, Radboud University
40 Medical Center, Nijmegen, The Netherlands.
- 41 7. Department of Dentistry-Quality and Safety of Oral Healthcare, Radboud University Medical
42 Center, Radboud Institute for Health Sciences, Nijmegen, The Netherlands
- 43 8. Department of Radiology, Nuclear Medicine and Anatomy, Radboud Institute for Health
44 Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.
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2
3 23 9. Department of General Surgery, Haaglanden Medical Centre, The Hague, The Netherlands.
4
5 24 10. Department of Urology, Radboud Institute for Health Sciences, Radboud University Medical
6
7 25 Center, Nijmegen, The Netherlands.
8
9 26 11. Department of Surgery, Radboud Institute for Health Sciences, Radboud University Medical
10
11 27 Center, Nijmegen, The Netherlands.
12
13
14 28 12. Department of Orthopedics, Radboud Institute for Health Sciences, Radboud University
15
16 29 Medical Center, Nijmegen, The Netherlands.
17
18 30 13. Orthopedic surgeon, Laurentius hospital Roermond
19
20 31 14. Department orthopedics, LUMC and OLVG, The Netherlands
21
22 32 15. Department of Surgery, University Medical Center Utrecht, The Netherlands
23
24 33 16. National Institute for Public Health and the Environment, PO Box 1, 3720 BA, Bilthoven,
25
26 34 Netherlands
27
28
29
30
31

32 36 Correspondence to: M M Rovers, Radboud university medical center, Department of Operatng
33
34 37 Rooms, route 715, PO Box 9101, 6500 HB Nijmegen, the Netherlands
35
36 38 E: Maroeska.Rovers@radboudumc.nl, T: +31-24-3651567
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49 **Abstract**

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

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

59 *Results:* To illustrate the framework, we studied 13 common elective procedures from four different
60 specialities. The highest loss in quality of life due to delayed surgery was found for total hip
61 replacement (utility loss of 0.27, i.e. 99 days lost in perfect health); the lowest for arthroscopic partial
62 meniscectomy (utility loss of 0.05, i.e. 18 days lost in perfect health). Costs of surgical delay per
63 patient were highest for bariatric surgery (€31/pp per week) and lowest for arthroscopic partial
64 meniscectomy (-€2/pp per week). Weighted by OR time bariatric surgery provides the most value
65 (€1.19/pp per OR minute), arthroscopic partial meniscectomy provides the least value (€0.34/pp per
66 OR minute). In a large hospital the net monetary loss due to prolonged waiting times was €700.840
67 after the first COVID-19 wave, an increase of 506% compared to the year before.

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

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3 75 **Strengths and limitations of this study**
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- 5 76 • We developed an evidence-based a surgical prioritization framework that can be used to
6
7 77 support priority setting for delayed elective operations during and after the COVID-19
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9 78 pandemic.
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12 79 • The framework is also available via an online tool (<https://stanwijn.shinyapps.io/priORitize/>),
13
14 80 that can easily be adapted according to local settings (e.g. regarding operation times) and
15
16 81 new available evidence
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19 82 • Since high-quality data regarding the consequences of the delay of surgery on deterioration
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21 83 are lacking, this could not be included in our model.
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23 84 • We used average data from literature rather than patient-level data, which could impact the
24
25 85 applicability of our results to the individual patient.
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34 89 **Keywords**

35
36 90 COVID-19, cancelled elective surgeries, OR capacity, OR prioritization, quality of life, cost, online
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38 91 framework
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43 93 **Word count abstract:** 362

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3 98 **Introduction**
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6 99 The extent to which the ongoing COVID-19 pandemic is disrupting global health, social welfare and
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9 100 the economy is unparalleled in modern history.[1] Due to this pandemic, hospitals, continue to have
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11 101 to drastically reduce elective surgeries. Current estimates suggest that worldwide more than 2
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13 102 million operations per week have been cancelled during the first wave of this pandemic, and most of
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15 103 them comprise elective surgeries.[2,3] It was also estimated that if countries increase their usual
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17 104 surgical volume by 20 percent after the pandemic, it would take about 45 weeks to clear the backlog
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19 105 due to the disruption.[2] With the current second wave and third waves, the number of delayed
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21 106 elective operations will only increase further. This not only affects the surgical disciplines, but also
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23 107 other related disciplines like gastroenterology, internal medicine, oncology, cardiology, neurology
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25 108 and general practitioners as they see the rise in time for referral of patients for surgery.
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30 109 The word “elective” implies that the indication for surgery is not ‘acute and life-saving’ like in the
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32 110 case of life-threatening emergency. In most hospitals ‘acute’ cases have been scheduled without
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34 111 restriction during the pandemic. For the elective cases, it is likely that their suboptimal health status
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36 112 persisted during the extended waiting period, but there might also be patients where the delay to
37
38 113 surgery may lead to deterioration of the disease and limit treatment options. However, it is also
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40 114 conceivable that their symptoms decrease during their extended waiting period, without affecting
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42 115 their personal life much, ultimately leading to cancelling of surgery.
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45 116 The COVID-19 pandemic provides a unique opportunity to study these effects of delay of elective
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47 117 surgeries. Moreover, the discussion on healthcare interventions where scientific support for addition
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49 118 of value is limited or even lacking, has also been reopened. That is, healthcare professionals also
50
51 119 have a responsibility to contribute to the affordability and accessibility of the healthcare system as a
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53 120 whole.[4,5] If healthcare can be made more sensible and qualitatively better, we can deliver more
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55 121 health care for less money. This requires not only a new mindset, but also reliable models and data
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57 122 to quantify the consequences of delay or even cancellation of surgery on patients and society.
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3 123 Models like ours will help to build an evidence-based framework which can be used to support
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5 124 priority setting for elective surgeries and subsequent optimisation of OR capacity. Therefore, our aim
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7 125 was to develop a framework to support priority setting for elective surgeries based on the impact on
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10 126 patient well-being and cost.
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130 **Methods**

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

137

138 *Selected elective procedures*

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

151

152 *[insert Table 1]*

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155 *Data acquisition and validation*

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3 156 For each case, input regarding cost and quality of life was derived from recent literature via
4
5 157 systematic literature searches in PubMed. Keywords included the disease of interest, the type of
6
7 158 surgery, length of stay, costs (resource use / healthcare utilization) and quality of life. The search
8
9 159 strategy can be found in Appendix 1. Ideally, a randomized controlled trial (RCT) or meta-analysis of
10
11 160 multiple RCT's comparing surgery to watchful waiting or non-surgical care, was used to inform the
12
13 161 model. If these were not available, alternative high-quality data sources, such as observational
14
15 162 cohort studies or equivalent alternatives, were retrieved. If studies comparing surgery to watchful
16
17 163 waiting or non-surgical care were not available, before and after surgical studies were used to
18
19 164 estimate the effect of postponing surgery. The quality of the studies was assessed using a checklist in
20
21 165 which we scored the validity of the operation times and utilities used. To validate our data, we also
22
23 166 compared them with data from the Dutch National Institute for Public Health and the Environment
24
25 167 (RIVM) that studied the consequences of delayed surgery for the Dutch government.[7]
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32 169 *Quality of life*

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34 170 Effectiveness was measured in terms of utility values, which reflects health-related quality of life on a
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36 171 0-1 scale, with 0 representing death and 1 representing full health. Utility values were derived from
37
38 172 the EQ-5D.[8,9] When available, differences in utilities between surgery and watchful waiting were
39
40 173 extracted at 6-12 months intervals to calculate the surgery associated gain in utility. If a watchful
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42 174 waiting cohort was not available, the baseline utility (measured before surgery) of surgical patients
43
44 175 was taken to calculate the surgery-associated gain in utility. We assumed that the surgery-associated
45
46 176 gain in utility represents the loss in utility due to delay of surgery. That is, if an operation that
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48 177 increases a patients utility with 0.2 is postponed for one year, we assume a total loss of quality of life
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50 178 of 0.2 over that year.
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3 182 *Costs*
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5 183 The extra health care expenditure due to waiting for surgery was determined by calculating the
6
7 184 difference in healthcare expenditure before and after surgery. Only costs from a healthcare
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10 185 perspective were included, e.g. extra visits to the hospital, general practitioner, physiotherapist. To
11
12 186 enable a comparison between procedures we extracted the resource use (e.g. number of extra
13
14 187 hospital visits) rather than the actual cost from literature. The resource use was multiplied by
15
16 188 standard unit prices for each procedure, ensuring a similar calculation of costs across operations.
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18 189 When available, unit prices were derived from the Dutch guideline for costing research.[10]
19
20 190 Otherwise, unit prices were obtained from hospital fees. We excluded medication costs since this
21
22 191 was often not reported or the reporting lacked detailed information necessary for our model. Costs
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24 192 were calculated in Euros (€) and based on the 2019 price level.
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30 194 *Operating time*
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33 195 Operating time was considered to be the total time the patient was in the operating theatre,
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35 196 including anaesthesia and surgery (skin-to-skin) time, and was extracted from literature. To validate
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37 197 these data, we compared them with the empirical data provided by two hospitals. Furthermore, in
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39 198 the online available framework, the operating time can be adjusted to match operating times for a
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41 199 specific setting.
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48 201 *Analysis*
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50 202 We calculated the loss of quality of life (in utilities) and extra costs per week delay of surgery. We
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52 203 also calculated the net monetary loss, which is defined as the total loss of waiting another week for
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54 204 surgery, expressed in monetary terms. The net monetary loss is calculated by multiplying the loss in
55
56 205 quality of life due to waiting one week for surgery by a threshold value, and subsequently the extra
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58 206 costs of waiting another week for surgery are added. We used a threshold value of €20,000 per year
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60

207 of full health, as recommended for conditions with a relatively low burden of disease by the Dutch
208 guidelines for cost-effectiveness.[10] As an example, let's assume a surgical procedure leads to a 0.2
209 gain in utility and a decrease in the patient's healthcare expenses of €50 per week. Delaying this
210 procedure for one week results in a net monetary loss of $(0.2 \times \frac{1}{52} \times \text{€}20,000) + \text{€}50 = \text{€}127$.

211 The procedure with the highest net monetary loss therewith provides the most 'value' when
212 prioritized. Subsequently, we also took into account the operating time since more patients can
213 benefit from procedures with short operating times given a fixed OR capacity. For example, when a
214 surgical procedure "X" can be performed twice in the timeframe of procedure "Y", procedure "Y" has
215 to result in twice as much value to have a similar value in the same OR time. Therefore, the net
216 monetary loss per week was weighted for the operating time, resulting in the net monetary loss per
217 week per OR minute.

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

222

223 *Empirical example*

224 To illustrate how our framework works and can be used in clinical practice, we applied it on real
225 world data from a large regional hospital in The Netherlands. Data used from this hospital comprise
226 the actual numbers of patients waiting for each of the 13 included procedures on June 30 in 2020,
227 2019 and 2018 and the average waiting time for each procedure in these years. Based on these data
228 we calculated the total net monetary loss after the first COVID-19 wave (June 30, 2020) as compared
229 to 2019 and 2018. This was done by multiplying the number of patients that are waiting by the
230 average waiting time and the net monetary loss for that procedure.

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3 233 *Interactive surgical prioritization framework*
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5 234 The decision-analytic models for the elective surgical procedures were wrapped in an interactive
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7 235 web-based framework developed to further stimulate engagement and discussion between the
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9 236 relevant stakeholders, i.e. surgical disciplines, anaesthesiology, other referring medical disciplines,
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11 237 and decision makers. By default, the interactive framework shows the results presented in this
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13 238 paper, but users of the framework can alter some of the parameters (e.g. the operation time) or
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15 239 select procedures relevant to their departments or strategy. In this way the framework can be used
16

17 240 on different strategic levels, i.e. department level or hospital level (for decisions across
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19 241 departments). The framework was built using R (version 4.0.2, The R Foundation for Statistical
20

21 242 Computing, Vienna, Austria) with shiny (version 1.5.0) and shinydashboard (version 0.7.1)
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23 243 packages.[11,12] The interactive framework is available via <https://stanwijn.shinyapps.io/priORitize/>
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3 246 **Results**
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7 248 *Quality of life*
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10 249 The highest loss in quality of life due to delayed surgery was found for total hip replacement (utility
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12 250 of 0.27, i.e. 99 days lost in perfect health when waiting for a year), followed by total shoulder and
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14 251 knee replacement (utilities of 0.22 and 0.22, i.e. 80 days lost in perfect health when waiting for a
15
16 252 year), respectively (Table 2). The lowest loss in quality of life was found for arthroscopic partial
17
18 253 meniscectomy (utility of 0.05, i.e. 18 days lost in perfect health when waiting for a year), see also
19
20 254 Figure 1. For sphincteroplasty, the male sling procedure, and the tension-free vaginal tape procedure
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22 255 utility values were not available in literature.
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28 257 *[insert Table 2]*
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30 258

31 259 *[insert Figures]*
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41 263 *Cost*
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43 264 Delay of both LSG and LRYGB bariatric surgery resulted in the highest costs (€31 pp per week),
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45 265 followed by partial colectomy for non-acute Crohn's disease (€17 pp per week), and ulcerative colitis
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47 266 (€16 pp per week). Delay of arthroscopic partial meniscectomy was found to result in the lowest
48
49 267 costs (-€2 pp per week), see also Figure 2. For sphincteroplasty, total shoulder replacement, male
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51 268 sling procedure, and tension-free vaginal tape procedure, no literature was available to determine
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53 269 the extra resource use due to waiting for surgery.
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3 272 *Net monetary loss*
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5 273 Combining the loss in quality of life and extra costs resulted in a calculation of the net monetary loss
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7 274 per week. Total hip replacement was found to result in the highest loss per week of delay (€114 per
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9 275 week per procedure), followed by total knee replacement (€95 per week per procedure), and partial
10
11 276 colectomy for non-acute Crohn's disease (€94 per week per procedure). Arthroscopic partial
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13 277 meniscectomy appears to result in the lowest loss per week (€18 per week per procedure), see also
14
15 278 Figure 3. It should be noted that the net monetary loss could only be calculated for procedures for
16
17 279 which we could find information regarding the quality of life and costs in the literature.
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23 281 *Net monetary loss weighted by operating time*
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25 282 When the OR time per procedure is taken into account, the net monetary loss per week per OR
26
27 283 minute shows that LSG provides the most value (€1.2 per week per OR minute), followed by LRYGB
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29 284 (€0.9 per week per OR minute), and total knee replacement (€0.9 per week per OR minute).
30
31 285 Arthroscopic partial meniscectomy seems to provide the least value (€0.3 per week per OR minute),
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33 286 see also Figure 4.
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39 288 *Impact of surgical delay*
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41 289 For the 13 included elective surgeries, we conservatively estimated that 30% was delayed for 3
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43 290 months as compared to the total number that was performed in the year before Covid-19 (i.e. 27,500
44
45 291 elective surgeries for the 13 included procedures). In total, a 30% delay in the 13 selected elective
46
47 292 surgical procedures resulted in €0.3 million extra costs for the healthcare system and a total impact
48
49 293 on both cost and quality of life of €3.6 million. The impact of a 10 to 50% surgical delay for each
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51 294 procedure can be found in Appendix 2.
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298 *Empirical example*

299 The impact of the COVID-19 crisis was clearly visible in the surgical waiting times of a large regional
300 hospital in The Netherlands (Appendix 3). After the first COVID-19 wave (i.e. on June 30, 2020), 624
301 patients were waiting for one of the 13 included procedures, while on the same day in 2019 and
302 2018, 291 and 257 patients were waiting. As a consequence, the total net monetary loss after the
303 first wave was €873.504, while the total net monetary losses were €172.664 and €124.224 in 2019
304 and 2018. Compared to June 30, 2019 and 2018, the total net monetary after the first wave
305 increased with 506% (€700.840) and with 703% (€749.280), respectively.

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309 Discussion

310 We developed a surgical prioritization framework that provides information that can be used to set
311 priorities in elective surgeries. For example, the highest loss in quality of life due to delayed surgery
312 was found for total hip replacement (utility of 0.27, i.e. 99 days lost in perfect health when waiting
313 for a year); the lowest for arthroscopic partial meniscectomy (utility of 0.05, i.e. 18 days lost in
314 perfect health when waiting for a year). Costs of surgical delay were highest for LSG and LRYGB
315 (€31/pp per week) and lowest for arthroscopic partial meniscectomy (-€2/pp per week). Total hip
316 replacement and total knee replacement resulted in the highest net monetary losses per week (€114
317 and €95, respectively), while septoplasty and arthroscopic partial meniscectomy had a net monetary
318 loss per week of €22 and €18, respectively. In case we assumed that 30% of the 13 included
319 procedures were delayed over a 3 month period as compared to the total numbers of procedures
320 performed a year earlier, the delay resulted in €0.3 million extra costs for the Dutch healthcare
321 system and a total impact on both cost and quality of life (net monetary loss) of €3.6 million. Data
322 from a large regional hospital in The Netherlands show that more than twice as many patients were
323 waiting for one of the 13 modelled operative procedures after the first COVID-19 wave as compared
324 to 2019 (624 versus 291 patients, respectively). Consequently, the extra net monetary loss caused by
325 these waiting times was €700.840, which is an increase of 506% compared to 2019.

326
327 Several other models to study the effect of delayed surgery and to inform surgical recovery plans
328 have been developed. Degeling et al. for example,[52] developed a model to estimate the impact of
329 delayed cancer diagnosis and treatment on survival outcomes and healthcare costs based on a shift
330 in the cancer disease stage at treatment initiation. They showed that a conservative 3-month delay in
331 cancer diagnosis and treatment due to the COVID-19 pandemic, results in an excess health cost of
332 \$12 million in Australia over 5 years for the in 2020 diagnosed patients for 4 cancers. Gravesteijn et
333 al.[53] also developed a model that supports prioritization of care. They, however, focused on semi-
334 elective surgeries, including cardiothoracic, oncological and transplantation surgery, whereas we

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3 335 focused on elective surgeries. Needless to say that cancer patients and patients awaiting organ
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5 336 transplantation have a completely different profile as far as prognosis of their disease on the one
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7 337 hand and burden of awaiting treatment, on the other, is concerned. Furthermore, they used the
8
9 338 global burden of disease by the WHO to estimate the QALY for 1/3 of the surgeries, and for the other
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11 339 2/3 they used estimates by an expert panel. Our quality of life data are based on literature data from
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13 340 comparative studies using validated quality of life measures, which is in agreement with the ISPOR
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15 341 recommendation to use health-utility data collected from patients.[54] Wang et al.[55] developed a
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17 342 framework to model surgical backlog recovery. In contrast to our model, they did not include quality
18
19 343 of life assessment to guide prioritization of care. They used available resources and bed capacity that
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21 344 are adjustable to other contexts, aiding region-specific decision-making. The COVIDSurg
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23 345 Collaborative[2] and Brandman et al.[56] separately developed models to predict the size of the
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25 346 backlog and time needed to restore this backlog. Although these models are different from the
26
27 347 present framework, combining both perspectives might result in a comprehensive context specific
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29 348 policy to clear the surgical backlog.

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35 349 The major strength of our approach is that the data used from literature are completely transparent
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37 350 in the online framework, and that it can easily be adapted according to local settings (e.g. regarding
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39 351 operation times) and new available evidence. Our model was built with high-quality QoL- and cost
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41 352 data that were derived from randomised controlled trials or comparative studies. We had the unique
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43 353 opportunity to cross validate our results to a national study by the Dutch Institute for Public Health
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45 354 and the Environment and empirical data from a large local hospital.[7] The concordance appeared to
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47 355 be very high with more than 75% overlap. Furthermore, by calculating the net monetary losses per
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49 356 week weighed by OR minute we were able to make a comparison between procedures and surgical
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51 357 disciplines based on the surgery time. This provides new insights on how to allocate valuable surgery
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53 358 time when comparing these operations, to maximize value.
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3 359 Some potential limitations should also be discussed. First, we used average data from literature
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5 360 rather than patient-level data, which could impact the applicability of our results to the individual
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7 361 patient. However, our goal was to develop a practical framework to support priority setting able to
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9 362 generalize and compare on department and surgery level instead. The model is therefore useful in
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11 363 general during the COVID-19 pandemic as well as for policy-making in striving for quality-driven
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13 364 healthcare.
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16 365 Second, we did not yet take into account other related factors such as ICU or personnel capacity, the
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18 366 number of beds available, the risk of exposing patients to perioperative COVID-19 infection, or
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20 367 psychological consequences. This was outside the scope of this paper but can be added in a future
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22 368 model, and of course these factors can be taken into account in the individual trade-off.
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25 369 Third, impact of waiting on medication costs (for example pain medication that patients need while
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27 370 waiting for surgery), could not be taken into account because they were either not reported in
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29 371 literature or not described in enough detail to be suitable for inclusion in the model. In order to be
30
31 372 able to take medication costs into account, better reporting of cost data, i.e. categorization of cost
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33 373 data, in clinical studies is needed. Furthermore, it could be expected that some patients need extra
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35 374 home care or had a prolonged stay in a nursing home because they are waiting for surgery. These
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37 375 costs were not reported in literature and were therefore not included in the model. Consequently,
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39 376 the total cost presented are an underestimation of the real cost.
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43 377 Fourth, besides impact on quality of life, delayed surgery may have a variety of consequences
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45 378 regarding the deterioration of the disease ranging from 'no harm' (varices, inguinal hernia) to
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47 379 'complications' (easy or difficult to treat, medically or surgically: Crohn's disease, ulcerative colitis) to
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49 380 disease-related death. Currently, high-quality data regarding the consequences of the delay of
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51 381 surgery on deterioration are lacking and could therefore not be included in our model. Because of
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53 382 the elective nature of the included procedures, we believe that deterioration with high impact (like
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55 383 disease-related death) will be limited. However, if this COVID-19 pandemic will prove that delaying
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3 384 the included procedures do lead to high impact deterioration it is necessary to include the
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5 385 consequences of delaying surgery, the model can be adapted accordingly.
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7 386 Fifth, so far, we only modelled 13 elective surgical procedures whereas there are many more. Since
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9 387 we developed an online framework, new data can easily be added to inform future decision making,
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11 388 for example additional high quality data comparing surgery to watchful waiting or non-surgical care.
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14 389 Others can also provide us with relevant information on other procedures, which we will check on
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16 390 consistency and validity, before adding them to the online framework.

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18 391 Sixth, for some procedures no data on quality of life or costs were available in literature. The fact
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20 392 that no relevant data were retrieved from literature for sphincteroplasty , male sling procedure, and
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22 393 tension-free vaginal tape procedure illustrates how difficult it is, and will be, to calculate the added
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24 394 value of these procedures. It renders this type of surgery 'vulnerable' in strategic discussions, but
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26 395 also stimulates groups active in this complex field to come up with data in support of continuing this
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28 396 type of operations. We are, however, aware of research projects that will follow the patients
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30 397 currently 'waiting' due to the backlog of the pandemic.[57] Hopefully, these projects will provide us
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32 398 with more accurate data, which are critical to obtain reliable estimates.
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39 400 The ongoing pandemic is having a collateral damage effect on health care and the delivery of surgical
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41 401 care to millions of patients worldwide. This is an effect that most certainly will persist for years to
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43 402 come. It is to be expected that cancer and other acute surgery, if cancelled during the pandemic, will
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45 403 be prioritized in most settings, whereas the impact on other elective surgeries for benign conditions
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47 404 will be cumulative, adding to the existing waiting times. Governments and other policy makers will
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49 405 be requested to fund substantial increases in surgical volume to clear backlogs, and this framework
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51 406 may help them to prioritize on evidence regarding QoL and cost savings rather than on a mixture of
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53 407 numbers and expert opinion.

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56 408 When addressing the backlog of postponed elective surgeries, it is tempting to start with surgeries
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58 409 that cause a high net monetary loss when delayed on the one hand and have large volumes on the
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3 410 other. However, as we look at bariatric surgery, we see a discrepancy between population impact
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5 411 and net monetary loss per OR minute. Although bariatric surgery has one of the highest net
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7 412 monetary losses of all procedures described in this paper, it has the lowest impact on population
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9 413 level due to small volumes. Also, when resuming total knee and total hip replacement first, huge
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11 414 numbers of patients need to be operated taking a lot of valuable OR time, while for bariatric surgery
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13 415 only a small number of patients needs to be operated. Therefore, we would like to emphasize that
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15 416 objective measures are indispensable for fair and justifiable prioritization of surgeries, and that these
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17 417 choices are preferably based on the net monetary loss per OR minute. Such medical care
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19 418 prioritisation data may add to future discussions on “appropriate use” of health care budgets.
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24
25 420 In conclusion, our online framework can be used in deciding how to address the postponed elective
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27 421 surgeries after the COVID-19 pandemic. Furthermore, the model will also be useful during possible
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29 422 future repeated waves of COVID-19 or in the long-term as it provides relevant information regarding
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31 423 an efficient distribution of OR time.
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3 428 **Declarations**
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7 430 **Competing interests**
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9
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13
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15
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18 435 submitted work
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23 437 **Licence**
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41 445 **Contributors and sources**
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46
47 448 have contributed to the final design of the paper. Modelling was performed by SW, SM, RV, MS, TG,
48
49 449 CM, MJ, IS and NvdB. Model input and feedback was received from RvdP, BB, HG, CT, MS, CR, SvdG,
50
51 450 TvT, RP, JR and NS. MR, SW, MS and TG drafted the manuscript. The online framework as developed
52
53 451 by SW. All authors have made contributions to the drafting and revising of the article. All authors
54
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12
13 459 responsibility for the integrity of the data and the accuracy of the data analysis. There was no
14
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21 462 **Patient and public involvement**
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23 463 It was not possible to involve patients or the public in the design, conduct, or reporting of our
24
25 464 research. Dissemination to participants and related patient and public communities: The framework
26
27 465 is available online at: <https://stanwijn.shinyapps.io/priORitize/>,
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32 467 **Transparency**
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34
35 468 The lead authors affirm that the manuscript is an honest, accurate, and transparent account of the
36
37 469 study being reported; and that no important aspects of the study have been omitted.
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42 471 **Data sharing**
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44 472 Detailed extracted data on all included elective surgical procedures are available in the online
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46 473 framework.
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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	Utility post-		Cost per week (€)	NML per week (€)	NML by	References	
		time (min)	Utility pre-surgery	surgery			Δ Utility		operating time (€)
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]

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

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

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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

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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

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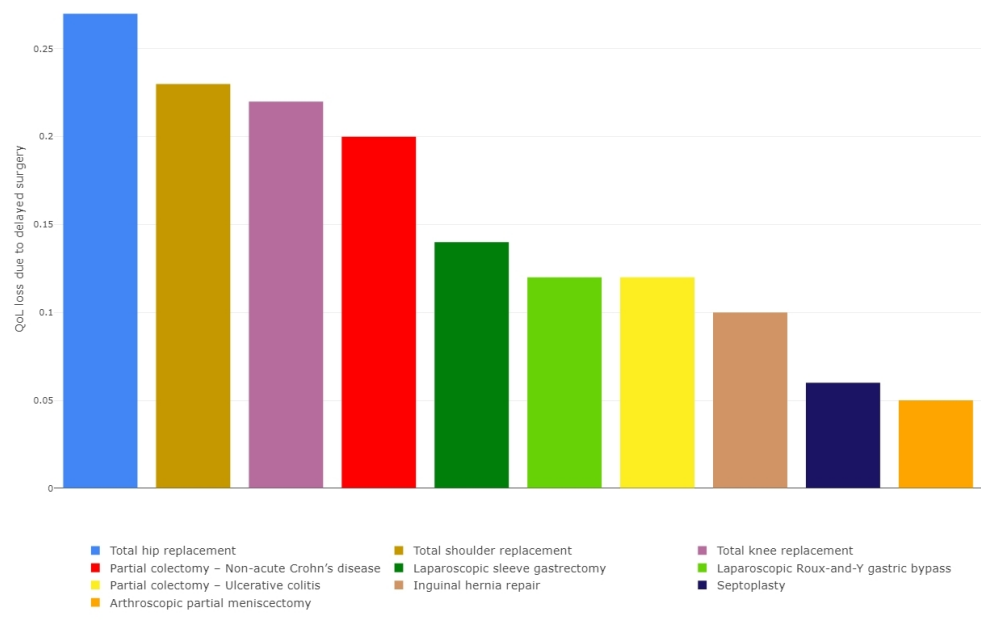
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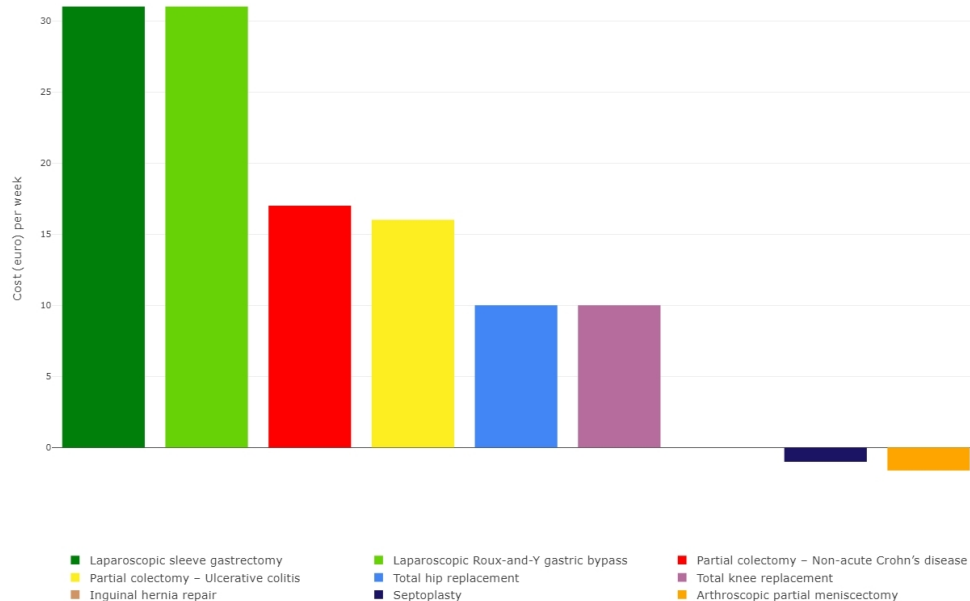
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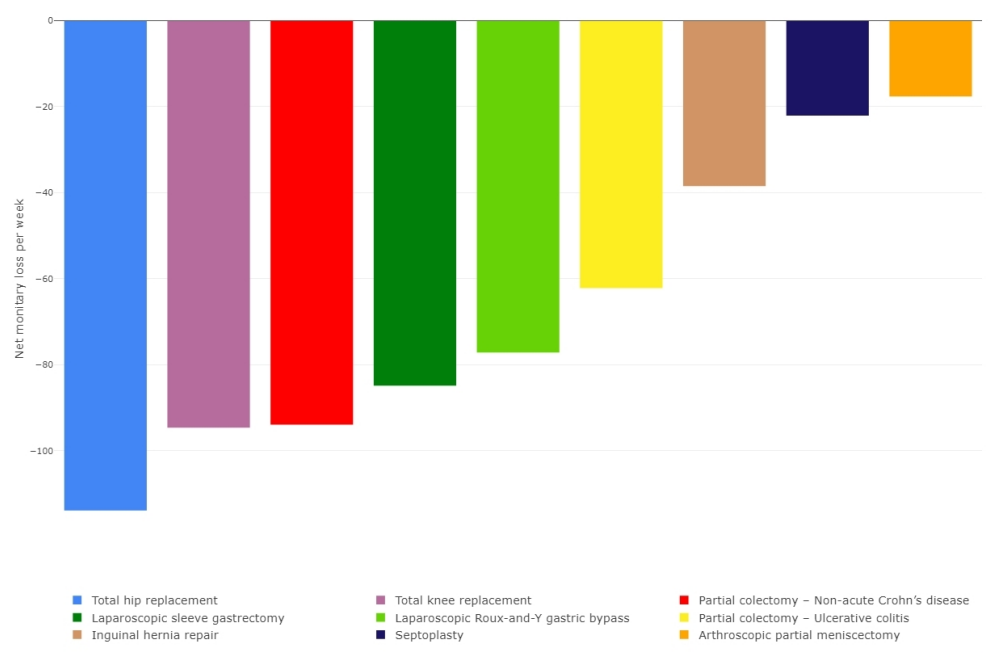
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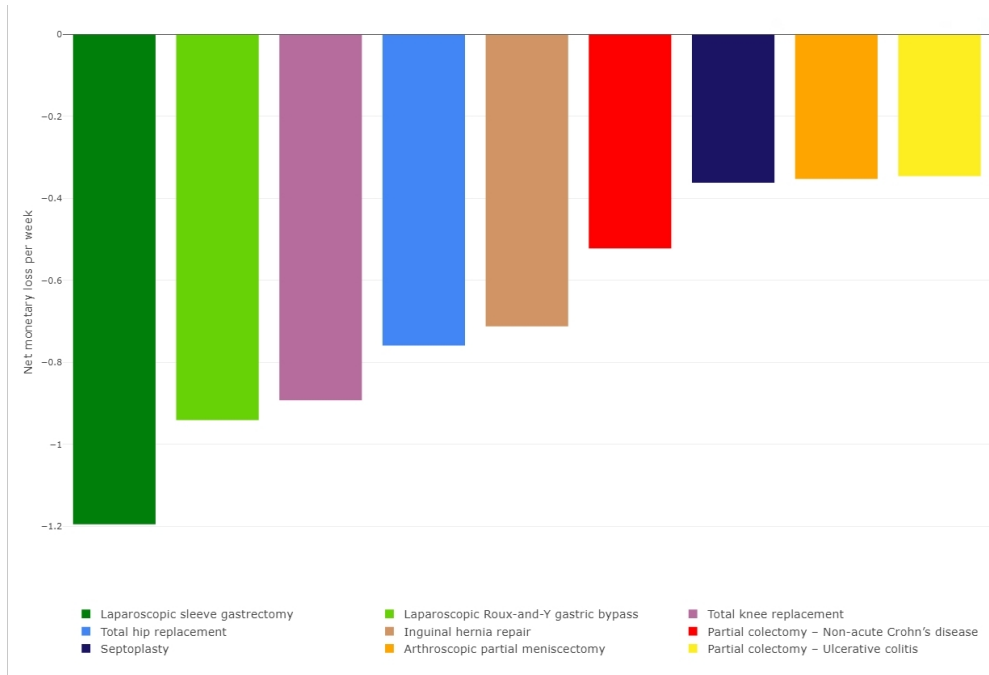
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Supplement S1: Search strategy for model data

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 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	€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.	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

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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

BMJ Open

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

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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

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3 **1 Lessons learned from delayed elective surgeries during the COVID-19**
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6 **2 pandemic: development of a decision analytical framework to prioritize**
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9 **3 operating room capacity**

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12 4 Authors:

13
14 5 *Maroeska M. Rovers^{1,2}, Stan R.W. Wijn¹, Janneke P. Grutters^{1,2}, Sanne Metsemakers¹, Robin*
15
16 6 *Vermeulen¹, Ron van der Pennen³, Bart Berden^{3,4}, Hein G. Gooszen¹, Mirre Scholte¹, Tim M. Govers¹*

17
18
19
20
21 8 Collaborators/acknowledgements:

22
23 9 *Charlotte Michels^{5,6}, Milica Jevdjovic⁷, Ilse Spenkelink⁸, Niels van den Berkmortel², Casper Tax⁹,*
24
25 10 *Michiel Sedelaar¹⁰, Camiel Rosman¹¹, Sebastiaan van der Goes¹², Tony van Tienen¹³, Rudolph*
26
27 11 *Poolman¹⁴, Jelle Ruurda¹⁵, Niek Stadhouders¹⁶, Paul van Leest³.*

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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

- 1
2
3 21 8. Department of Radiology, Nuclear Medicine and Anatomy, Radboud Institute for Health
4
5 22 Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.
6
7 23 9. Department of General Surgery, Haaglanden Medical Centre, The Hague, The Netherlands.
8
9
10 24 10. Department of Urology, Radboud Institute for Health Sciences, Radboud University Medical
11
12 25 Center, Nijmegen, The Netherlands.
13
14 26 11. Department of Surgery, Radboud Institute for Health Sciences, Radboud University Medical
15
16 27 Center, Nijmegen, The Netherlands.
17
18 28 12. Department of Orthopedics, Radboud Institute for Health Sciences, Radboud University
19
20 29 Medical Center, Nijmegen, The Netherlands.
21
22
23 30 13. Orthopedic surgeon, Laurentius hospital Roermond
24
25 31 14. Department orthopedics, LUMC and OLVG, The Netherlands
26
27 32 15. Department of Surgery, University Medical Center Utrecht, The Netherlands
28
29 33 16. National Institute for Public Health and the Environment, PO Box 1, 3720 BA, Bilthoven,
30
31 34 Netherlands
32
33
34 35
35
36 36 Correspondence to: M M Rovers, Radboud university medical center, Department of Operatng
37
38 Rooms, route 715, PO Box 9101, 6500 HB Nijmegen, the Netherlands
39
40 41 E: Maroeska.Rovers@radboudumc.nl, T: +31-622726370
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1
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3 39 **Abstract**
4

5 40 *Objective:* To develop a prioritization framework to support priority setting for elective surgeries
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7 41 after COVID-19 based on the impact on patient well-being and cost.

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9 42 *Design:* We developed decision analytic models to estimate the consequences of delayed elective
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11 43 surgical procedures (e.g. total hip replacement, bariatric surgery or septoplasty)

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13
14 44 *Setting:* The framework was applied to a large hospital in the Netherlands.

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16 45 *Outcome measures:* impacts on quality of life and costs were taken into account and combined to
17
18 46 calculate net monetary losses per week delay, which quantifies the total loss for society expressed in
19
20 47 monetary terms. Net monetary losses were weighted by operating times.

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23 48 *Results:* We studied 13 common elective procedures from four specialities. Highest loss in quality of
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25 49 life due to delayed surgery was found for total hip replacement (utility loss of 0.27, i.e. 99 days lost in
26
27 50 perfect health); the lowest for arthroscopic partial meniscectomy (utility loss of 0.05, i.e. 18 days lost
28
29 51 in perfect health). Costs of surgical delay per patient were highest for bariatric surgery (€31/pp per
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31 52 week) and lowest for arthroscopic partial meniscectomy (-€2/pp per week). Weighted by OR time
32
33 53 bariatric surgery provides most value (€1.19/pp per OR minute), arthroscopic partial meniscectomy
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35 54 provides the least value (€0.34/pp per OR minute). In a large hospital the net monetary loss due to
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37 55 prolonged waiting times was €700.840 after the first COVID-19 wave, an increase of 506% compared
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39 56 to the year before.

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43 57 *Conclusions:* This surgical prioritization framework can be tailored to specific centres and countries to
44
45 58 support priority setting for delayed elective operations during and after the COVID-19 pandemic,
46
47 59 both in and between surgical disciplines. In the long-term, the framework can contribute to the
48
49 60 efficient distribution of OR time and will therefore add to the discussion on appropriate use of health
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51 61 care budgets. The online framework can be accessed via: <https://stanwijn.shinyapps.io/priORitize/>
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3 65 **Strengths and limitations of this study**
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- 5 66 • Decision analytical modelling appears to be an efficient tool to compare the impact of delays
6
7 67 in elective surgery due to the COVID-19 pandemic on patient quality of life and healthcare
8
9 68 costs.
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11 69 • The framework is available via an online tool that can easily be adapted according to local
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13 70 settings (e.g. regarding operation times, currencies) and new available evidence.
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15 71 • Since high-quality data regarding the consequences of the delay of surgery on deterioration
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17 72 are lacking, this could not be included in our model.
18
19 73 • We used average data from literature rather than patient-level data, which could impact the
20
21 74 applicability of our results to the individual patient.
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28 76 **Keywords**

29
30 77 COVID-19, cancelled elective surgeries, OR capacity, OR prioritization, quality of life, cost, online
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32 78 framework
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37 80 **Word count abstract:** 300

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39 81 **Word count main text** (Background through Conclusions): 4194
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83 Introduction

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

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

103 The COVID-19 pandemic provides a unique opportunity to study these effects of delay of elective
104 surgeries. Moreover, the discussion on healthcare interventions where scientific support for addition
105 of value is limited or even lacking, has also been reopened. That is, healthcare professionals also
106 have a responsibility to contribute to the affordability and accessibility of the healthcare system as a
107 whole.[6,7] If healthcare can be made more sensible and qualitatively better, we can deliver more

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3 108 health care for less money. This requires not only a new mindset, but also reliable models and data
4
5 109 to quantify the consequences of delay or even cancellation of surgery on patients and society.
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7 110 Models like ours will help to build an evidence-based framework which can be used to support
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9 111 priority setting for elective surgeries and subsequent optimisation of OR capacity. Therefore, our aim
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11 112 was to develop a framework to support priority setting for elective surgeries based on the impact on
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14 113 patient well-being and cost.
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For peer review only

115 **Methods**

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

125

126 *Selected elective procedures*

127 All procedures that could wait for at least 2 months after diagnosis according to the urgency
128 categories of the Dutch Healthcare Authority during the early phase of the COVID-19 pandemic were
129 considered for our model.[9] Clinical experts from multiple specialties were consulted to determine
130 useful examples of clinical dilemmas in times of COVID-19. We decided to compare procedures
131 within and between specialties to demonstrate how to prioritize within and between disciplines. The
132 following elective procedures were included: general and gastrointestinal surgical procedures
133 (inguinal hernia repair, laparoscopic sleeve gastrectomy (LSG), Roux-en-Y laparoscopic gastric bypass
134 (LRYGB), partial colectomy for non-acute Crohn's disease & ulcerative colitis, sphincteroplasty),
135 urological/gynaecological procedures (male sling procedure, tension free vaginal tape procedure),
136 orthopaedic procedures (total hip replacement, total knee replacement, total shoulder replacement,
137 arthroscopic partial meniscectomy), and one otorhinolaryngological procedure (septoplasty) (Table
138 1).

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

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144 *Data acquisition and validation*
145 For each case, input regarding cost and quality of life was derived from recent literature via semi-
146 systematic literature searches in PubMed. Keywords included the disease of interest, the type of
147 surgery, length of stay, costs (resource use / healthcare utilization) and quality of life. The search
148 strategy can be found in Supplement S2. Ideally, a randomized controlled trial (RCT) or meta-analysis
149 of multiple RCT's comparing surgery to watchful waiting or non-surgical care, was used to inform the
150 model. If these were not available, alternative high-quality data sources, such as observational
151 cohort studies or equivalent alternatives, were retrieved. If studies comparing surgery to watchful
152 waiting or non-surgical care were not available, before and after surgical studies were used to
153 estimate the effect of postponing surgery. The quality of the studies was assessed using a checklist in
154 which we scored the validity of the operation times and utilities used. In addition, for each case study
155 a clinical expert was consulted to ensure that all important aspects of the patient population, disease

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3 156 and surgery were captured. To validate our data, we also compared them with data from the Dutch
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5 157 National Institute for Public Health and the Environment (RIVM) that studied the consequences of
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7 158 delayed surgery for the Dutch government.[10]
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11 160 *Quality of life*

12 161 Effectiveness was measured in terms of utility values, which reflects health-related quality of life on a
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14 162 0-1 scale, with 0 representing death and 1 representing full health. Utility values were derived from
15
16 163 the EQ-5D questionnaire.[11,12] When available, differences in utilities between surgery and
17
18 164 watchful waiting were extracted at 6-12 months intervals to calculate the gain in utility which can be
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20 165 reached by performing the surgery. If a watchful waiting cohort was not available, the baseline utility
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22 166 (measured before surgery) of surgical patients was taken to calculate the gain in utility which can be
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24 167 reached by performing the surgery.
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29 168 We assumed that gain in utility that can be reached by performing a surgery represents the loss in
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31 169 utility in case surgery is delayed. That is, if an operation that increases a patients utility with 0.2 is
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33 170 postponed for one year, we assume a total loss of utility of 0.2 over that year. Figure 1a shows how
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35 171 we calculated the impact of delayed surgery on the loss of quality of life (in utility values).
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40 173 *[insert Figure 1]*

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42 175 *Costs*

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47 176 The extra health care expenditure due to waiting for surgery was determined by calculating the
48
49 177 difference in healthcare expenditure before and after surgery (Figure 1b). Only costs from a
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51 178 healthcare perspective were included, e.g. extra visits to the hospital, general practitioner,
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53 179 physiotherapist. Costs of surgery itself were not included, as we assumed that all patients would
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55 180 receive surgery. To enable a comparison between procedures we extracted the resource use (e.g.
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3 181 number of extra hospital visits) rather than the actual cost from literature. The resource use was
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5 182 multiplied by standard unit prices for each procedure, ensuring a similar calculation of costs across
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7 183 operations. When available, unit prices were derived from the Dutch guideline for costing
8
9 184 research.[13] Otherwise, unit prices were obtained from hospital fees. We excluded medication costs
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11 185 since this was often not reported or the reporting lacked detailed information necessary for our
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14 186 model. Costs were calculated in Euros (€) and based on the 2019 price level.

17 187 *Operating time*

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20 188 Operating time for all surgical procedures was extracted from literature to weigh the impact of
21
22 189 surgery against the time needed to perform the surgery (see analysis). Operating time was
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24 190 considered to be the total time the patient was in the operating theatre, including anaesthesia and
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26 191 surgery (skin-to-skin) time, and was extracted from literature. To validate these data, we compared
27
28 192 them with the empirical data provided by two hospitals. Furthermore, in the online available
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30 193 framework, the operating time can be adjusted to match operating times for a specific setting.

34 194 *Analysis*

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37 195 We calculated the loss of quality of life (in utilities) and extra costs per week delay of surgery based
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39 196 on the obtained utility values and costs. Subsequently, we calculated the net monetary loss, which is
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41 197 defined as the total loss of waiting another week for surgery, expressed in monetary terms. The net
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43 198 monetary loss is calculated by multiplying the loss in quality of life due to waiting one week for
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45 199 surgery by a threshold value, and subsequently the extra costs of waiting another week for surgery
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47 200 are added. We used a threshold value of €20,000 per year of full health, as recommended for
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49 201 conditions with a relatively low burden of disease by the Dutch guidelines for cost-effectiveness
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51 202 (Figure 1c).[13] As an example, let's assume a surgical procedure leads to a 0.2 gain in utility and a
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53 203 decrease in the patient's healthcare expenses of €50 per week. Delaying this procedure for one week
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57 204 results in a net monetary loss of $\left(0.2 \times \frac{1}{52} \times €20,000\right) + €50 = €127$. The procedure with the

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3 205 highest net monetary loss therewith provides the most 'value' when prioritized. Subsequently, we
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5 206 also took into account the operating time since more patients can benefit from procedures with
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7 207 short operating times given a fixed OR capacity. For example, when a surgical procedure "X" can be
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9 208 performed twice in the timeframe of procedure "Y", procedure "Y" has to result in twice as much
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11 209 value to have a similar value in the same OR time (Figure 1d). Therefore, the net monetary loss per
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13 210 week was weighted for the operating time, resulting in the net monetary loss per week per OR
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15 211 minute.

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18 212 Last, we calculated the impact of postponing these elective surgeries during one of the COVID-19
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20 213 waves, assuming 30% delay in these 13 elective surgeries over a 3 month period as compared to the
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22 214 year before. We calculated the impact of postponing elective surgeries in total costs and total net
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24 215 monetary loss.

25 26 27 28 216 *Empirical example*

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32 217 To illustrate how our framework works and can be used in clinical practice, we applied it on real
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34 218 world data from a large regional hospital in The Netherlands. Data used from this hospital comprise
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36 219 the actual numbers of patients waiting for each of the 13 included procedures on June 30 in 2020,
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38 220 2019 and 2018 and the average waiting time for each procedure in these years. Based on these data
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40 221 we calculated the total net monetary loss after the first COVID-19 wave (June 30, 2020) as compared
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42 222 to 2019 and 2018. This was done by multiplying the number of patients that are waiting by the
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44 223 average waiting time and the net monetary loss for that procedure.

45 46 47 48 224 *Interactive surgical prioritization framework*

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52 225 The decision-analytic models for the elective surgical procedures were wrapped in an interactive
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54 226 web-based framework developed to further stimulate engagement and discussion between the
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56 227 relevant stakeholders, i.e. surgical disciplines, anaesthesiology, other referring medical disciplines,
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58 228 and decision makers. By default, the interactive framework shows the results presented in this
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3 229 paper, but users of the framework can alter some of the parameters (e.g. the operation time) or
4
5 230 select procedures relevant to their departments or strategy. In this way the framework can be used
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7 231 on different strategic levels, i.e. department level or hospital level (for decisions across
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9 232 departments). Furthermore, cost prices of the different resources and currencies can be altered to
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11 233 make the framework applicable for other countries. The framework was built using R (version 4.0.2,
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13 234 The R Foundation for Statistical Computing, Vienna, Austria) with shiny (version 1.5.0) and
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15 235 shinydashboard (version 0.7.1) packages.[14,15] The interactive framework is available via
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17 236 <https://stanwijn.shinyapps.io/priORitize/>
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21 237 *Patient and Public Involvement*
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23 238 There was no patient or public involvement in the study.
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239 **Results**240 *Quality of life*

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

249 **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	-€	-€ 0.8	Expert opinion	[43,44]	[45-48]	
Total knee replacement	Orthopaedic surgery	106	0.51	0.73	0.22	€ 10	-€	-€ 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	-€	-€ 0.3	Expert opinion	[56]	[56]	
Septoplasty	Otorhinolaryngology	61	0.83	0.89	0.06	-€ 1	-€	-€ 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.

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 252 [insert Figure 2]
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 254 Cost
 255 Delay of both LSG and LRYGB bariatric surgery resulted in the highest costs (€31 pp per week),
 256 followed by partial colectomy for non-acute Crohn's disease (€17 pp per week), and ulcerative colitis
 257 (€16 pp per week). Delay of arthroscopic partial meniscectomy was found to result in the lowest
 258 costs (-€2 pp per week), see also Figure 2b. For sphincteroplasty, total shoulder replacement, male

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3 259 sling procedure, and tension-free vaginal tape procedure, no literature was available to determine
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5 260 the extra resource use due to waiting for surgery.
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8 261 *Net monetary loss*

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11 262 Combining the loss in quality of life and extra costs resulted in a calculation of the net monetary loss
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13 263 per week. Total hip replacement was found to result in the highest loss per week of delay (€114 per
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15 264 week per procedure), followed by total knee replacement (€95 per week per procedure), and partial
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17 265 colectomy for non-acute Crohn's disease (€94 per week per procedure). Arthroscopic partial
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19 266 meniscectomy appears to result in the lowest loss per week (€18 per week per procedure), see also
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21 267 Figure 2c. It should be noted that the net monetary loss could only be calculated for procedures for
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23 268 which we could find information regarding the quality of life and costs in the literature.
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28 269 *Net monetary loss weighted by operating time*

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31 270 When the OR time per procedure is taken into account, the net monetary loss per week per OR
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33 271 minute shows that LSG provides the most value (€1.2 per week per OR minute), followed by LRYGB
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35 272 (€0.9 per week per OR minute), and total knee replacement (€0.9 per week per OR minute).
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37 273 Arthroscopic partial meniscectomy seems to provide the least value (€0.3 per week per OR minute),
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39 274 see also Figure 2d.
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44 275 *Impact of surgical delay*

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47 276 For the 13 included elective surgeries, we conservatively estimated that 30% was delayed for 3
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49 277 months as compared to the total number that was performed in the year before Covid-19 (i.e. 27,500
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51 278 elective surgeries for the 13 included procedures). In total, a 30% delay in the 13 selected elective
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53 279 surgical procedures resulted in €0.3 million extra costs for the healthcare system and a total impact
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55 280 on both cost and quality of life of €3.6 million. The impact of a 10 to 50% surgical delay for each
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57 281 procedure can be found in Supplement S3.
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282 *Empirical example*

283 The impact of the COVID-19 crisis was clearly visible in the surgical waiting times of a large regional
284 hospital in The Netherlands (Supplement S4). After the first COVID-19 wave (i.e. on June 30, 2020),
285 624 patients were waiting for one of the 13 included procedures, while on the same day in 2019 and
286 2018, 291 and 257 patients were waiting. As a consequence, the total net monetary loss after the
287 first wave was €873.504, while the total net monetary losses were €172.664 and €124.224 in 2019
288 and 2018. Compared to June 30, 2019 and 2018, the total net monetary after the first wave
289 increased with 506% (€700.840) and with 703% (€749.280), respectively.

290 Discussion

291 We developed a surgical prioritization framework that provides information that can be used to set
292 priorities in elective surgeries. For example, the highest loss in quality of life due to delayed surgery
293 was found for total hip replacement (utility of 0.27, i.e. 99 days lost in perfect health when waiting
294 for a year); the lowest for arthroscopic partial meniscectomy (utility of 0.05, i.e. 18 days lost in
295 perfect health when waiting for a year). Costs of surgical delay were highest for LSG and LRYGB
296 (€31/pp per week) and lowest for arthroscopic partial meniscectomy (-€2/pp per week). Total hip
297 replacement and total knee replacement resulted in the highest net monetary losses per week (€114
298 and €95, respectively), while septoplasty and arthroscopic partial meniscectomy had a net monetary
299 loss per week of €22 and €18, respectively. In case we assumed that 30% of the 13 included
300 procedures were delayed over a 3 month period as compared to the total numbers of procedures
301 performed a year earlier, the delay resulted in €0.3 million extra costs for the Dutch healthcare
302 system and a total impact on both cost and quality of life (net monetary loss) of €3.6 million. Data
303 from a large regional hospital in The Netherlands show that more than twice as many patients were
304 waiting for one of the 13 modelled operative procedures after the first COVID-19 wave as compared
305 to 2019 (624 versus 291 patients, respectively). Consequently, the extra net monetary loss caused by
306 these waiting times was €700.840, which is an increase of 506% compared to 2019.

307
308 Several other models to study the effect of delayed surgery and to inform surgical recovery plans
309 have been developed. Degeling et al. for example,[16] developed a model to estimate the impact of
310 delayed cancer diagnosis and treatment on survival outcomes and healthcare costs based on a shift
311 in the cancer disease stage at treatment initiation. They showed that a conservative 3-month delay in
312 cancer diagnosis and treatment due to the COVID-19 pandemic, results in an excess health cost of
313 \$12 million in Australia over 5 years for the in 2020 diagnosed patients for 4 cancers. Gravesteijn et
314 al.[17] also developed a model that supports prioritization of care. They, however, focused on semi-
315 elective surgeries, including cardiothoracic, oncological and transplantation surgery, whereas we

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3 316 focused on elective surgeries. Needless to say that cancer patients and patients awaiting organ
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5 317 transplantation have a completely different profile as far as prognosis of their disease on the one
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7 318 hand and burden of awaiting treatment, on the other, is concerned. Furthermore, they used the
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9 319 global burden of disease by the WHO to estimate the QALY for 1/3 of the surgeries, and for the other
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11 320 2/3 they used estimates by an expert panel. Our quality of life data are based on literature data from
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13 321 comparative studies using validated quality of life measures, which is in agreement with the ISPOR
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15 322 recommendation to use health-utility data collected from patients.[18] Wang et al.[19] developed a
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17 323 framework to model surgical backlog recovery. In contrast to our model, they did not include quality
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19 324 of life assessment to guide prioritization of care. They used available resources and bed capacity that
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21 325 are adjustable to other contexts, aiding region-specific decision-making. The COVIDSurg
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23 326 Collaborative[2] and Brandman et al.[20] separately developed models to predict the size of the
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25 327 backlog and time needed to restore this backlog. Although these models are different from the
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27 328 present framework, combining both perspectives might result in a comprehensive context specific
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29 329 policy to clear the surgical backlog.
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38 331 The major strength of our approach is that the data used from literature are completely transparent
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40 332 in the online framework, and that it can easily be adapted according to local settings (e.g. regarding
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42 333 operation times) and new available evidence. Our model was built with high-quality QoL- and cost
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44 334 data that were derived from randomised controlled trials or comparative studies. We had the unique
45
46 335 opportunity to cross validate our results to a national study by the Dutch Institute for Public Health
47
48 336 and the Environment and empirical data from a large local hospital.[10] The concordance appeared
49
50 337 to be very high with more than 75% overlap. Furthermore, by calculating the net monetary losses per
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52 338 week weighed by OR minute we were able to make a comparison between procedures and surgical
53
54 339 disciplines based on the surgery time. This provides new insights on how to allocate valuable surgery
55
56 340 time when comparing these operations, to maximize value.
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3 341 Some potential limitations should also be discussed. First, we used average data from literature
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5 342 rather than patient-level data, which could impact the applicability of our results to the individual
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7 343 patient. However, our goal was to develop a practical framework to support priority setting able to
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9 344 generalize and compare on department and surgery level instead. The model is therefore useful in
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11 345 general during the COVID-19 pandemic as well as for policy-making in striving for quality-driven
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14 346 healthcare.

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16 347 Second, we did not yet take into account other related factors such as ICU or personnel capacity, the
17
18 348 number of beds available, the risk of exposing patients to perioperative COVID-19 infection, or
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20 349 psychological consequences. This was outside the scope of this paper but can be added in a future
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22 350 model, and of course these factors can be taken into account in the individual trade-off.

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25 351 Third, impact of waiting on medication costs (for example pain medication that patients need while
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27 352 waiting for surgery), could not be taken into account because they were either not reported in
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29 353 literature or not described in enough detail to be suitable for inclusion in the model. In order to be
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31 354 able to take medication costs into account, better reporting of cost data, i.e. categorization of cost
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33 355 data, in clinical studies is needed. Furthermore, it could be expected that some patients need extra
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35 356 home care or had a prolonged stay in a nursing home because they are waiting for surgery. These
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37 357 costs were not reported in literature and were therefore not included in the model. Consequently,
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39 358 the total cost presented are an underestimation of the real cost.

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43 359 Fourth, besides impact on quality of life, delayed surgery may have a variety of consequences
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45 360 regarding the deterioration of the disease ranging from 'no harm' (varices, inguinal hernia) to
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47 361 'complications' (easy or difficult to treat, medically or surgically: Crohn's disease, ulcerative colitis) to
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49 362 disease-related death. Currently, high-quality data regarding the consequences of the delay of
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51 363 surgery on deterioration are lacking and could therefore not be included in our model. Because of
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53 364 the elective nature of the included procedures, we believe that deterioration with high impact (like
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55 365 disease-related death) will be limited. However, if this COVID-19 pandemic will prove that delaying
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3 366 the included procedures do lead to high impact deterioration it is necessary to include the
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5 367 consequences of delaying surgery, the model can be adapted accordingly.
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7 368 Fifth, so far, we only modelled 13 elective surgical procedures whereas there are many more. Since
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9 369 we developed an online framework, new data can easily be added to inform future decision making,
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11 370 for example additional high quality data comparing surgery to watchful waiting or non-surgical care.
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13 371 Others can also provide us with relevant information on other procedures, which we will check on
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15 372 consistency and validity, before adding them to the online framework.
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17 373 Sixth, for some procedures no data on quality of life or costs were available in literature. The fact
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19 374 that no relevant data were retrieved from literature for sphincteroplasty , male sling procedure, and
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21 375 tension-free vaginal tape procedure illustrates how difficult it is, and will be, to calculate the added
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23 376 value of these procedures. It renders this type of surgery 'vulnerable' in strategic discussions, but
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25 377 also stimulates groups active in this complex field to come up with data in support of continuing this
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27 378 type of operations. We are, however, aware of research projects that will follow the patients
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29 379 currently 'waiting' due to the backlog of the pandemic.[21] Hopefully, these projects will provide us
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31 380 with more accurate data, which are critical to obtain reliable estimates.
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35 382 The ongoing pandemic is having a collateral damage effect on health care and the delivery of surgical
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37 383 care to millions of patients worldwide. This is an effect that most certainly will persist for years to
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39 384 come. It is to be expected that cancer and other acute surgery, if cancelled during the pandemic, will
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41 385 be prioritized in most settings, whereas the impact on other elective surgeries for benign conditions
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43 386 will be cumulative, adding to the existing waiting times. Governments and other policy makers will
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45 387 be requested to fund substantial increases in surgical volume to clear backlogs, and this framework
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47 388 may help them to prioritize on evidence regarding QoL and cost savings rather than on a mixture of
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49 389 numbers and expert opinion.
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51 390 When addressing the backlog of postponed elective surgeries, it is tempting to start with surgeries
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53 391 that cause a high net monetary loss when delayed on the one hand and have large volumes on the
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3 392 other. However, as we look at bariatric surgery, we see a discrepancy between population impact
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5 393 and net monetary loss per OR minute. Although bariatric surgery has one of the highest net
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7 394 monetary losses of all procedures described in this paper, it has the lowest impact on population
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9 395 level due to small volumes. Also, when resuming total knee and total hip replacement first, huge
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11 396 numbers of patients need to be operated taking a lot of valuable OR time, while for bariatric surgery
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13 397 only a small number of patients needs to be operated. Therefore, we would like to emphasize that
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15 398 objective measures are indispensable for fair and justifiable prioritization of surgeries, and that these
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17 399 choices are preferably based on the net monetary loss per OR minute. Such medical care
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19 400 prioritisation data may add to future discussions on “appropriate use” of health care budgets.
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25 402 In conclusion, our online framework can be used in deciding how to address the postponed elective
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27 403 surgeries after the COVID-19 pandemic. Furthermore, the model will also be useful during possible
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29 404 future repeated waves of COVID-19 or in the long-term as it provides relevant information regarding
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31 405 an efficient distribution of OR time.
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3 407 **Figure legends**
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7 409 Figure 1: Overview of the methods used. 1a: Loss in quality of life (QoL) due to delayed or postponed
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9 410 surgery was calculated by extracting the QoL before surgery from the QoL after surgery and
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11 411 multiplying this with the duration of the delay (one week in our analyses). 1b: The costs (in €)
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13 412 associated with waiting for surgery were calculated by extracting the average costs after surgery
14
15 413 from the average costs before surgery and multiplying this with the duration of the delay (one week
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17 414 in our analyses). 1c: The net monetary loss (monetary measure to calculate the total societal loss of
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19 415 delaying surgery) was calculated by multiplying the loss in QoL by the willingness to pay (€ 20,000)
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21 416 and adding the extra costs associated with waiting for surgery. The willingness to pay represents the
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23 417 amount of money society is willing to pay for one year in full health. 1d: Surgery associated net
24
25 418 monetary loss per week divided by operating time. Relevant when trying to optimize the operating
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27 419 schedule. During a two hour surgery, also two operations of one hour could be performed. In other
28
29 420 words, the two hour surgery needs to be associated with twice as much NML as the 1 hour surgeries
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31 421 to be as worthwhile to perform.
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38 423 Figure 2: Overview of results. 2a: Loss in quality of life (QoL) due to delayed or postponed surgery
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40 424 expressed as a utility score. A utility reflects QoL on a 0 to 1 scale, with 0 representing death and 1
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42 425 representing full health. 2b: Extra health care expenditure due to waiting for surgery. 2c: The net
43
44 426 monetary loss combines QoL and costs due to waiting for surgery, it is therefore the total loss of
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46 427 waiting another week for surgery, expressed in monetary terms. 2d: Surgery associated net
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48 428 monetary loss per week divided by operating time (i.e. it reflects the total cost per week per OR
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50 429 minute).
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3 431 **Declarations**
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7 433 **Competing interests**
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9
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13
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15
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18 438 submitted work
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23 440 **Licence**
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25 441

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41 448 **Contributors and sources**
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43 449

45 450 MR, SW, JG, HG, MS and TG have contributed to the conception and design of the study. All authors
46
47 451 have contributed to the final design of the paper. Modelling was performed by SW, SM, RV, MS, TG,
48
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50
51 453 TvT, RP, JR and NS. MR, SW, MS and TG drafted the manuscript. The online framework as developed
52
53 454 by SW. All authors have made contributions to the drafting and revising of the article. All authors
54
55 455 have read, reviewed and approved the final version of the manuscript before submission.
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12
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15 463 commercial involvement in the study.
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23 466 **Transparency**
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25
26 467 The lead authors affirm that the manuscript is an honest, accurate, and transparent account of the
27
28 468 study being reported; and that no important aspects of the study have been omitted.
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33 470 **Data availability statement**
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35 471 All data used in this study were derived from sources available in the public domain. For references
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37 472 please refer to Table 2 or the online tool: <https://stanwijn.shinyapps.io/priORitize/>
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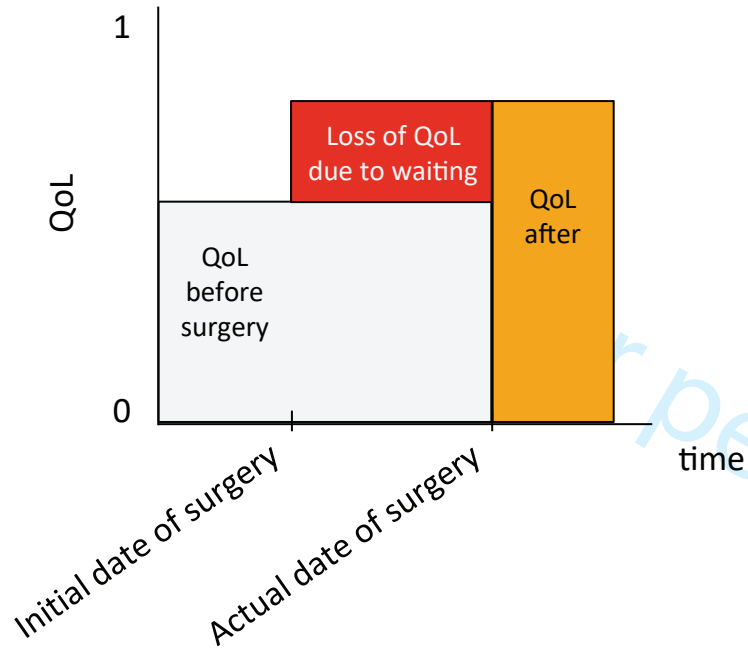
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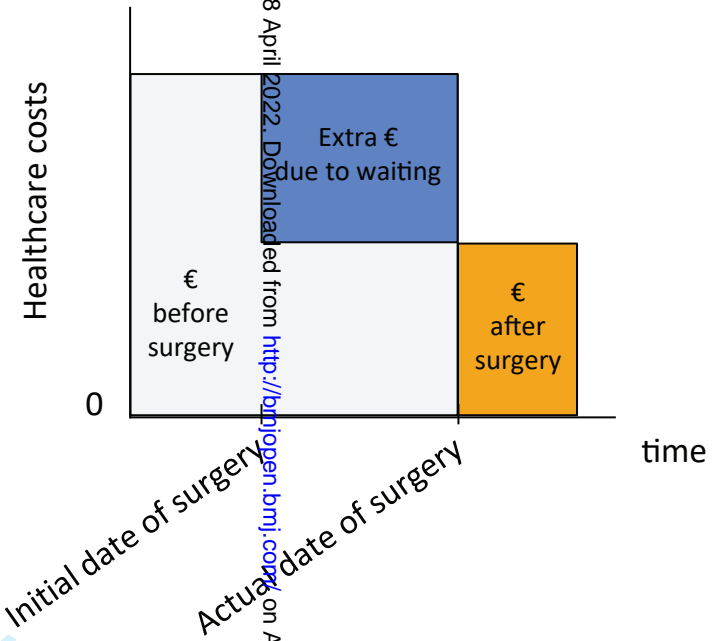
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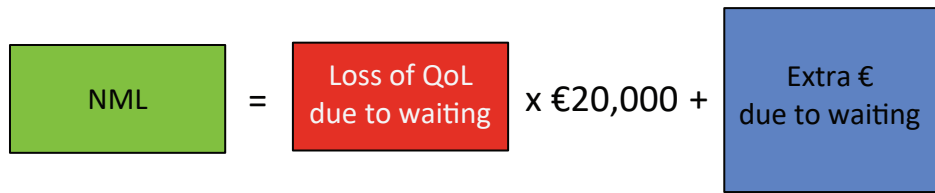
Loss in quality of life due to delayed surgery



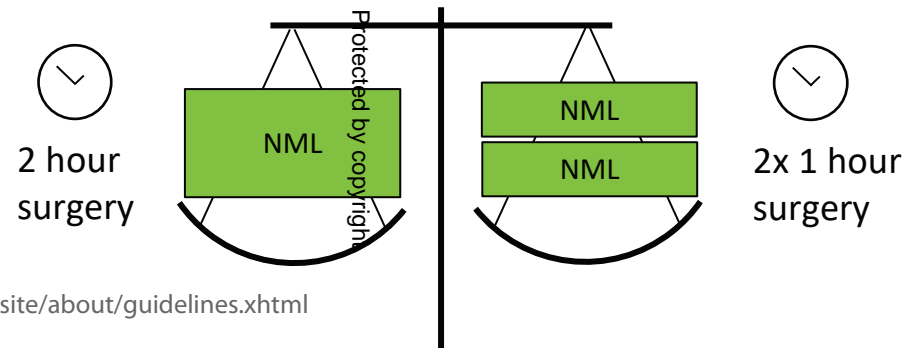
Cost associated with waiting for surgery



Surgery associated net monetary loss

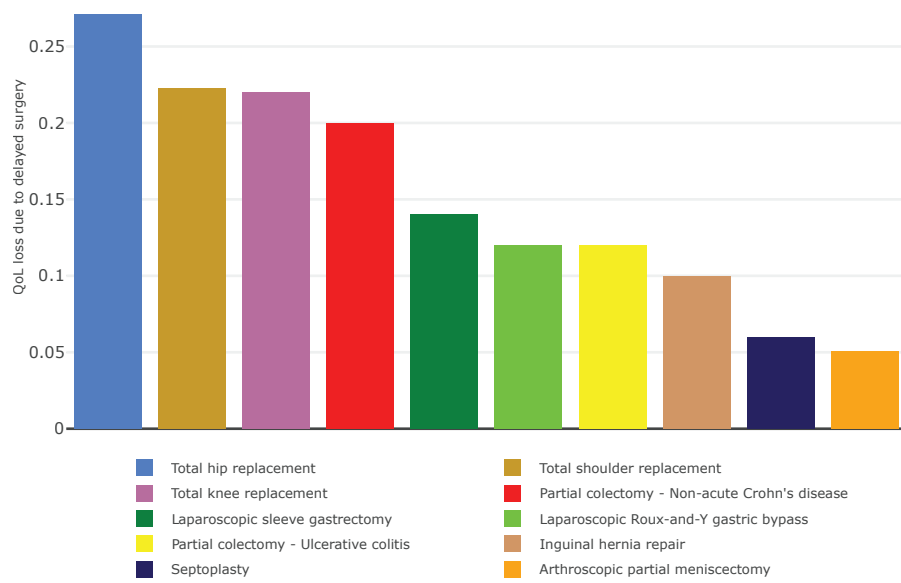


Net monetary loss weighted by operating time

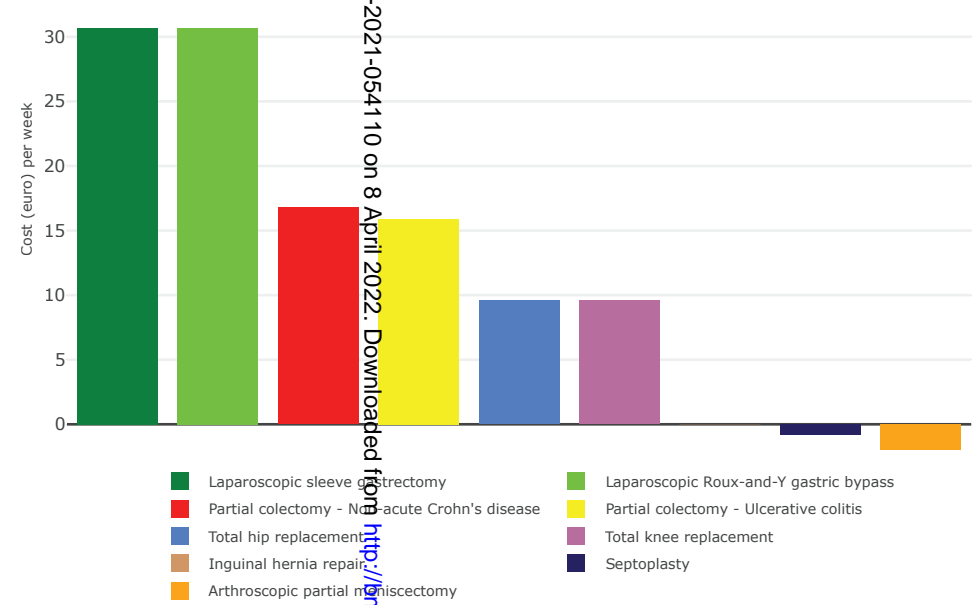


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Loss in quality of life due to delayed surgery

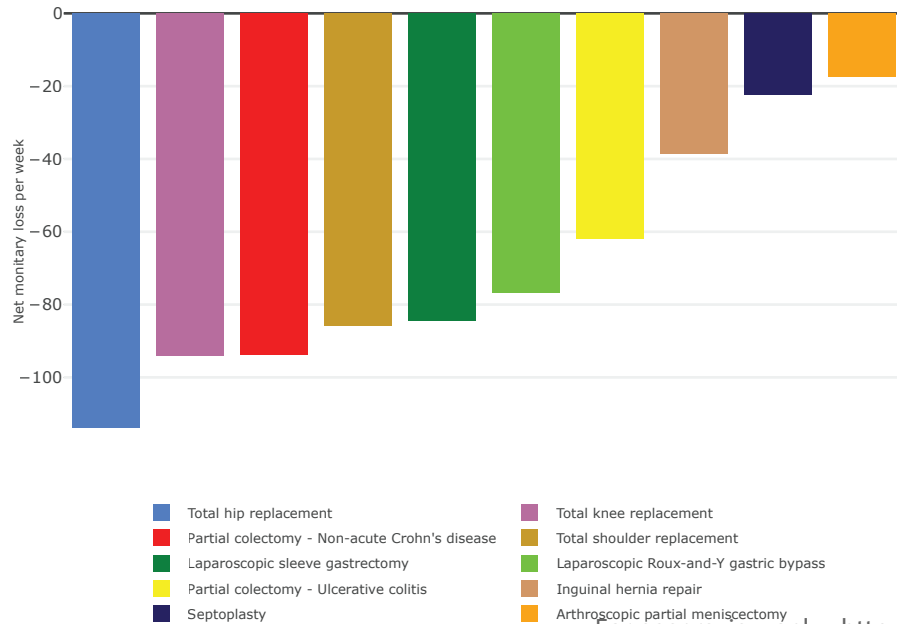


Cost associated with waiting for surgery (per week)



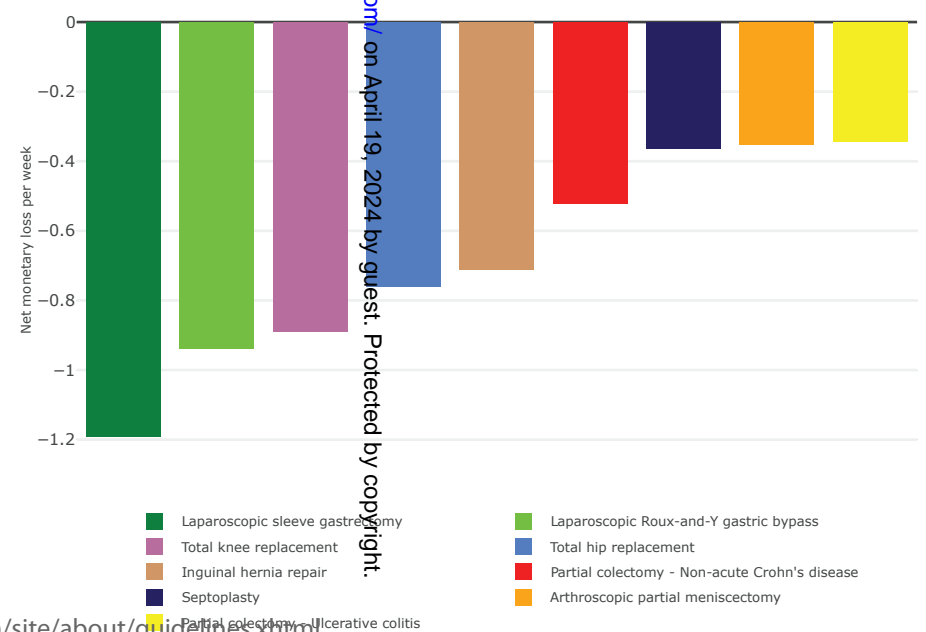
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Surgery associated net monetary loss per week



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Surgery associated net monetary loss weighted by operating time



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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)

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7	Study findings,	26	Report key findings,	discussion section
8	limitations,		limitations, ethical or	
9	generalisability, and		equity considerations	
10	current knowledge		not captured, and how	
11			these could affect	
12			patients, policy, or	
13			practice.	
14	Other relevant			
15	information			
16	Source of funding	27	Describe how the study	role of the funding
17			was funded and any role	source statement
18			of the funder in the	
19			identification, design,	
20			conduct, and reporting	
21			of the analysis	
22	Conflicts of interest	28	Report authors conflicts	competing interests
23			of interest according to	statement
24			journal or International	
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32	<i>From:</i> Husereau D, Drummond M, Augustovski F, et al. Consolidated Health Economic Evaluation Reporting			
33	Standards 2022 (CHEERS 2022) Explanation and Elaboration: A Report of the ISPOR CHEERS II Good			
34	Practices Task Force. Value Health 2022;25. doi:10.1016/j.jval.2021.10.008			
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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	€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.	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

BMJ Open

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

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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

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1 Development of a decision analytical framework to prioritize operating room 2 capacity: Lessons learned from an empirical example on delayed elective 3 surgeries during the COVID-19 pandemic in an hospital in the Netherlands

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5 Authors:

6 *Maroeska M. Rovers^{1,2}, Stan R.W. Wijn¹, Janneke P. Grutters^{1,2}, Sanne Metsemakers¹, Robin*

7 *Vermeulen¹, Ron van der Pennen³, Bart Berden^{3,4}, Hein G. Gooszen¹, Mirre Scholte¹, Tim M. Govers¹*

8
9 Collaborators/acknowledgements:

10 *Charlotte Michels^{5,6}, Milica Jevdjovic⁷, Ilse Spenkelink⁸, Niels van den Berkmortel², Casper Tax⁹,*

11 *Michiel Sedelaar¹⁰, Camiel Rosman¹¹, Sebastiaan van der Goes¹², Tony van Tienen¹³, Rudolph*

12 *Poolman¹⁴, Jelle Ruurda¹⁵, Niek Stadhouders¹⁶, Paul van Leest³.*

- 13
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

- 1
2
3 22 8. Department of Radiology, Nuclear Medicine and Anatomy, Radboud Institute for Health
4
5 23 Sciences, Radboud University Medical Center, Nijmegen, The Netherlands.
6
7 24 9. Department of General Surgery, Haaglanden Medical Centre, The Hague, The Netherlands.
8
9
10 25 10. Department of Urology, Radboud Institute for Health Sciences, Radboud University Medical
11
12 26 Center, Nijmegen, The Netherlands.
13
14 27 11. Department of Surgery, Radboud Institute for Health Sciences, Radboud University Medical
15
16 28 Center, Nijmegen, The Netherlands.
17
18 29 12. Department of Orthopedics, Radboud Institute for Health Sciences, Radboud University
19
20 30 Medical Center, Nijmegen, The Netherlands.
21
22
23 31 13. Orthopedic surgeon, Laurentius hospital Roermond
24
25 32 14. Department orthopedics, LUMC and OLVG, The Netherlands
26
27 33 15. Department of Surgery, University Medical Center Utrecht, The Netherlands
28
29 34 16. National Institute for Public Health and the Environment, PO Box 1, 3720 BA, Bilthoven,
30
31 Netherlands
32
33
34 36
35
36 37 Correspondence to: M M Rovers, Radboud university medical center, Department of Operating
37
38 38 Rooms, route 715, PO Box 9101, 6500 HB Nijmegen, the Netherlands
39
40
41 39 E: Maroeska.Rovers@radboudumc.nl, T: +31-622726370
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3 **40 Abstract**
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5 **41 Objective:** To develop a prioritization framework to support priority setting for elective surgeries
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7 **42** after COVID-19 based on the impact on patient well-being and cost.

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9 **43 Design:** We developed decision analytic models to estimate the consequences of delayed elective
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11 **44** surgical procedures (e.g. total hip replacement, bariatric surgery or septoplasty)

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14 **45 Setting:** The framework was applied to a large hospital in the Netherlands.

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16 **46 Outcome measures:** impacts on quality of life and costs were taken into account and combined to
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18 **47** calculate net monetary losses per week delay, which quantifies the total loss for society expressed in
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20 **48** monetary terms. Net monetary losses were weighted by operating times.

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23 **49 Results:** We studied 13 common elective procedures from four specialities. Highest loss in quality of
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25 **50** life due to delayed surgery was found for total hip replacement (utility loss of 0.27, i.e. 99 days lost in
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27 **51** perfect health); the lowest for arthroscopic partial meniscectomy (utility loss of 0.05, i.e. 18 days lost
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29 **52** in perfect health). Costs of surgical delay per patient were highest for bariatric surgery (€31/pp per
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31 **53** week) and lowest for arthroscopic partial meniscectomy (-€2/pp per week). Weighted by OR time
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33 **54** bariatric surgery provides most value (€1.19/pp per OR minute), arthroscopic partial meniscectomy
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35 **55** provides the least value (€0.34/pp per OR minute). In a large hospital the net monetary loss due to
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37 **56** prolonged waiting times was €700.840 after the first COVID-19 wave, an increase of 506% compared
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39 **57** to the year before.

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43 **58 Conclusions:** This surgical prioritization framework can be tailored to specific centres and countries to
44
45 **59** support priority setting for delayed elective operations during and after the COVID-19 pandemic,
46
47 **60** both in and between surgical disciplines. In the long-term, the framework can contribute to the
48
49 **61** efficient distribution of OR time and will therefore add to the discussion on appropriate use of health
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51 **62** care budgets. The online framework can be accessed via: <https://stanwijn.shinyapps.io/priORitize/>
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3 66 **Strengths and limitations of this study**
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- 5 67 • Decision analytical modelling appears to be an efficient tool to compare the impact of delays
6
7 68 in elective surgery due to the COVID-19 pandemic on patient quality of life and healthcare
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9 69 costs.
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12 70 • The framework is available via an online tool that can easily be adapted according to local
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14 71 settings (e.g. regarding operation times, currencies) and new available evidence.
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16 72 • Since high-quality data regarding the consequences of the delay of surgery on deterioration
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18 73 are lacking, this could not be included in our model.
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21 74 • We used average data from literature rather than patient-level data, which could impact the
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23 75 applicability of our results to the individual patient.
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27
28 77 **Keywords**

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30 78 COVID-19, cancelled elective surgeries, OR capacity, OR prioritization, quality of life, cost, online
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32 79 framework
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37 81 **Word count abstract:** 300

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39 82 **Word count main text** (Background through Conclusions): 4194
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84 Introduction

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

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

104 The COVID-19 pandemic provides a unique opportunity to study these effects of delay of elective
105 surgeries. Moreover, the discussion on healthcare interventions where scientific support for addition
106 of value is limited or even lacking, has also been reopened. That is, healthcare professionals also
107 have a responsibility to contribute to the affordability and accessibility of the healthcare system as a
108 whole.[6,7] If healthcare can be made more sensible and qualitatively better, we can deliver more

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3 109 health care for less money. This requires not only a new mindset, but also reliable models and data
4
5 110 to quantify the consequences of delay or even cancellation of surgery on patients and society.
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7 111 Models like ours will help to build an evidence-based framework which can be used to support
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9 112 priority setting for elective surgeries and subsequent optimisation of OR capacity. Therefore, our aim
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11 113 was to develop a framework to support priority setting for elective surgeries based on the impact on
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14 114 patient well-being and cost.
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116 **Methods**

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

127 *Selected elective procedures*

128 All procedures that could wait for at least 2 months after diagnosis according to the urgency
129 categories of the Dutch Healthcare Authority during the early phase of the COVID-19 pandemic were
130 considered for our model.[9] Clinical experts from multiple specialties were consulted to determine
131 useful examples of clinical dilemmas in times of COVID-19. We decided to compare procedures
132 within and between specialties to demonstrate how to prioritize within and between disciplines. The
133 following elective procedures were included: general and gastrointestinal surgical procedures
134 (inguinal hernia repair, laparoscopic sleeve gastrectomy (LSG), Roux-en-Y laparoscopic gastric bypass
135 (LRYGB), partial colectomy for non-acute Crohn's disease & ulcerative colitis, sphincteroplasty),
136 urological/gynaecological procedures (male sling procedure, tension free vaginal tape procedure),
137 orthopaedic procedures (total hip replacement, total knee replacement, total shoulder replacement,
138 arthroscopic partial meniscectomy), and one otorhinolaryngological procedure (septoplasty) (Table
139 1).

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

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32 145 *Data acquisition and validation*

33 146 For each case, input regarding cost and quality of life was derived from recent literature via semi-
34 147 systematic literature searches in PubMed. Keywords included the disease of interest, the type of
35 148 surgery, length of stay, costs (resource use / healthcare utilization) and quality of life. The search
36 149 strategy can be found in Supplement S2. Ideally, a randomized controlled trial (RCT) or meta-analysis
37 150 of multiple RCT's comparing surgery to watchful waiting or non-surgical care, was used to inform the
38 151 model. If these were not available, alternative high-quality data sources, such as observational
39 152 cohort studies or equivalent alternatives, were retrieved. If studies comparing surgery to watchful
40 153 waiting or non-surgical care were not available, before and after surgical studies were used to
41 154 estimate the effect of postponing surgery. The quality of the studies was assessed using a checklist in
42 155 which we scored the validity of the operation times and utilities used. In addition, for each case study
43 156 a clinical expert was consulted to ensure that all important aspects of the patient population, disease

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3 157 and surgery were captured. To validate our data, we also compared them with data from the Dutch
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5 158 National Institute for Public Health and the Environment (RIVM) that studied the consequences of
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7 159 delayed surgery for the Dutch government.[10]
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11 161 *Quality of life*

12 162 Effectiveness was measured in terms of utility values, which reflects health-related quality of life on a
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14 163 0-1 scale, with 0 representing death and 1 representing full health. Utility values were derived from
15
16 164 the EQ-5D questionnaire.[11,12] When available, differences in utilities between surgery and
17
18 165 watchful waiting were extracted at 6-12 months intervals to calculate the gain in utility which can be
19
20 166 reached by performing the surgery. If a watchful waiting cohort was not available, the baseline utility
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22 167 (measured before surgery) of surgical patients was taken to calculate the gain in utility which can be
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24 168 reached by performing the surgery.
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29 169 We assumed that gain in utility that can be reached by performing a surgery represents the loss in
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31 170 utility in case surgery is delayed. That is, if an operation that increases a patients utility with 0.2 is
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33 171 postponed for one year, we assume a total loss of utility of 0.2 over that year. Figure 1a shows how
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35 172 we calculated the impact of delayed surgery on the loss of quality of life (in utility values).
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41 174 *[insert Figure 1]*
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46 176 *Costs*

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49 177 The extra health care expenditure due to waiting for surgery was determined by calculating the
50
51 178 difference in healthcare expenditure before and after surgery (Figure 1b). Only costs from a
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53 179 healthcare perspective were included, e.g. extra visits to the hospital, general practitioner,
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55 180 physiotherapist. Costs of surgery itself were not included, as we assumed that all patients would
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57 181 receive surgery. To enable a comparison between procedures we extracted the resource use (e.g.
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3 182 number of extra hospital visits) rather than the actual cost from literature. The resource use was
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5 183 multiplied by standard unit prices for each procedure, ensuring a similar calculation of costs across
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7 184 operations. When available, unit prices were derived from the Dutch guideline for costing
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10 185 research.[13] Otherwise, unit prices were obtained from hospital fees. We excluded medication costs
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12 186 since this was often not reported or the reporting lacked detailed information necessary for our
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14 187 model. Costs were calculated in Euros (€) and based on the 2019 price level.

17 188 *Operating time*

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20 189 Operating time for all surgical procedures was extracted from literature to weigh the impact of
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22 190 surgery against the time needed to perform the surgery (see analysis). Operating time was
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24 191 considered to be the total time the patient was in the operating theatre, including anaesthesia and
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26 192 surgery (skin-to-skin) time, and was extracted from literature. To validate these data, we compared
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28 193 them with the empirical data provided by two hospitals. Furthermore, in the online available
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30 194 framework, the operating time can be adjusted to match operating times for a specific setting.

34 195 *Analysis*

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37 196 We calculated the loss of quality of life (in utilities) and extra costs per week delay of surgery based
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39 197 on the obtained utility values and costs. Subsequently, we calculated the net monetary loss, which is
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41 198 defined as the total loss of waiting another week for surgery, expressed in monetary terms. The net
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43 199 monetary loss is calculated by multiplying the loss in quality of life due to waiting one week for
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45 200 surgery by a threshold value, and subsequently the extra costs of waiting another week for surgery
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47 201 are added. We used a threshold value of €20,000 per year of full health, as recommended for
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49 202 conditions with a relatively low burden of disease by the Dutch guidelines for cost-effectiveness
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51 203 (Figure 1c).[13] As an example, let's assume a surgical procedure leads to a 0.2 gain in utility and a
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53 204 decrease in the patient's healthcare expenses of €50 per week. Delaying this procedure for one week
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58 205 results in a net monetary loss of $\left(0.2 \times \frac{1}{52} \times €20,000\right) + €50 = €127$. The procedure with the
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3 206 highest net monetary loss therewith provides the most 'value' when prioritized. Subsequently, we
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5 207 also took into account the operating time since more patients can benefit from procedures with
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7 208 short operating times given a fixed OR capacity. For example, when a surgical procedure "X" can be
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9 209 performed twice in the timeframe of procedure "Y", procedure "Y" has to result in twice as much
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11 210 value to have a similar value in the same OR time (Figure 1d). Therefore, the net monetary loss per
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13 211 week was weighted for the operating time, resulting in the net monetary loss per week per OR
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15 212 minute.

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18 213 Last, we calculated the impact of postponing these elective surgeries during one of the COVID-19
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20 214 waves, assuming 30% delay in these 13 elective surgeries over a 3 month period as compared to the
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22 215 year before. We calculated the impact of postponing elective surgeries in total costs and total net
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24 216 monetary loss.

27 28 29 217 *Empirical example*

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32 218 To illustrate how our framework works and can be used in clinical practice, we applied it on real
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34 219 world data from a large regional hospital in The Netherlands. Data used from this hospital comprise
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36 220 the actual numbers of patients waiting for each of the 13 included procedures on June 30 in 2020,
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38 221 2019 and 2018 and the average waiting time for each procedure in these years. Based on these data
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40 222 we calculated the total net monetary loss after the first COVID-19 wave (June 30, 2020) as compared
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42 223 to 2019 and 2018. This was done by multiplying the number of patients that are waiting by the
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44 224 average waiting time and the net monetary loss for that procedure.

45 46 47 48 225 *Interactive surgical prioritization framework*

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51 226 The decision-analytic models for the elective surgical procedures were wrapped in an interactive
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53 227 web-based framework developed to further stimulate engagement and discussion between the
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55 228 relevant stakeholders, i.e. surgical disciplines, anaesthesiology, other referring medical disciplines,
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57 229 and decision makers. By default, the interactive framework shows the results presented in this
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3 230 paper, but users of the framework can alter some of the parameters (e.g. the operation time) or
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5 231 select procedures relevant to their departments or strategy. In this way the framework can be used
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7 232 on different strategic levels, i.e. department level or hospital level (for decisions across
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9 233 departments). Furthermore, cost prices of the different resources and currencies can be altered to
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11 234 make the framework applicable for other countries. The framework was built using R (version 4.0.2,
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14 235 The R Foundation for Statistical Computing, Vienna, Austria) with shiny (version 1.5.0) and
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16 236 shinydashboard (version 0.7.1) packages.[14,15] The interactive framework is available via
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18 237 <https://stanwijn.shinyapps.io/priORitize/>

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21 238 *Patient and Public Involvement*

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23 239 There was no patient or public involvement in the study.
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240 **Results**

241 *Quality of life*

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

250 **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	-€	-€ 0.8	Expert opinion	[37,38]	[39-42]
Total knee replacement	Orthopaedic surgery	106	0.51	0.73	0.22	€ 10	-€	-€ 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	-€	-€ 0.3	Expert opinion	[50]	[50]
Septoplasty	Otorhinolaryngology	61	0.83	0.89	0.06	-€ 1	-€	-€ 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.

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 253 [insert Figure 2]
 254
 255 Cost
 256 Delay of both LSG and LRYGB bariatric surgery resulted in the highest costs (€31 pp per week),
 257 followed by partial colectomy for non-acute Crohn's disease (€17 pp per week), and ulcerative colitis
 258 (€16 pp per week). Delay of arthroscopic partial meniscectomy was found to result in the lowest
 259 costs (-€2 pp per week), see also Figure 2b. For sphincteroplasty, total shoulder replacement, male

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3 260 sling procedure, and tension-free vaginal tape procedure, no literature was available to determine
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5 261 the extra resource use due to waiting for surgery.
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8 262 *Net monetary loss*
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11 263 Combining the loss in quality of life and extra costs resulted in a calculation of the net monetary loss
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13 264 per week. Total hip replacement was found to result in the highest loss per week of delay (€114 per
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15 265 week per procedure), followed by total knee replacement (€95 per week per procedure), and partial
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17 266 colectomy for non-acute Crohn's disease (€94 per week per procedure). Arthroscopic partial
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19 267 meniscectomy appears to result in the lowest loss per week (€18 per week per procedure), see also
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21 268 Figure 2c. It should be noted that the net monetary loss could only be calculated for procedures for
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23 269 which we could find information regarding the quality of life and costs in the literature.
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28 270 *Net monetary loss weighted by operating time*
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31 271 When the OR time per procedure is taken into account, the net monetary loss per week per OR
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33 272 minute shows that LSG provides the most value (€1.2 per week per OR minute), followed by LRYGB
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35 273 (€0.9 per week per OR minute), and total knee replacement (€0.9 per week per OR minute).
36
37 274 Arthroscopic partial meniscectomy seems to provide the least value (€0.3 per week per OR minute),
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39 275 see also Figure 2d.
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44 276 *Impact of surgical delay*
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47 277 For the 13 included elective surgeries, we conservatively estimated that 30% was delayed for 3
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49 278 months as compared to the total number that was performed in the year before Covid-19 (i.e. 27,500
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51 279 elective surgeries for the 13 included procedures). In total, a 30% delay in the 13 selected elective
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53 280 surgical procedures resulted in €0.3 million extra costs for the healthcare system and a total impact
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55 281 on both cost and quality of life of €3.6 million. The impact of a 10 to 50% surgical delay for each
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57 282 procedure can be found in Supplement S3.
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283 *Empirical example*

284 The impact of the COVID-19 crisis was clearly visible in the surgical waiting times of a large regional
285 hospital in The Netherlands (Supplement S4). After the first COVID-19 wave (i.e. on June 30, 2020),
286 624 patients were waiting for one of the 13 included procedures, while on the same day in 2019 and
287 2018, 291 and 257 patients were waiting. As a consequence, the total net monetary loss after the
288 first wave was €873.504, while the total net monetary losses were €172.664 and €124.224 in 2019
289 and 2018. Compared to June 30, 2019 and 2018, the total net monetary after the first wave
290 increased with 506% (€700.840) and with 703% (€749.280), respectively.

291 Discussion

292 We developed a surgical prioritization framework that provides information that can be used to set
293 priorities in elective surgeries. For example, the highest loss in quality of life due to delayed surgery
294 was found for total hip replacement (utility of 0.27, i.e. 99 days lost in perfect health when waiting
295 for a year); the lowest for arthroscopic partial meniscectomy (utility of 0.05, i.e. 18 days lost in
296 perfect health when waiting for a year). Costs of surgical delay were highest for LSG and LRYGB
297 (€31/pp per week) and lowest for arthroscopic partial meniscectomy (-€2/pp per week). Total hip
298 replacement and total knee replacement resulted in the highest net monetary losses per week (€114
299 and €95, respectively), while septoplasty and arthroscopic partial meniscectomy had a net monetary
300 loss per week of €22 and €18, respectively. In case we assumed that 30% of the 13 included
301 procedures were delayed over a 3 month period as compared to the total numbers of procedures
302 performed a year earlier, the delay resulted in €0.3 million extra costs for the Dutch healthcare
303 system and a total impact on both cost and quality of life (net monetary loss) of €3.6 million. Data
304 from a large regional hospital in The Netherlands show that more than twice as many patients were
305 waiting for one of the 13 modelled operative procedures after the first COVID-19 wave as compared
306 to 2019 (624 versus 291 patients, respectively). Consequently, the extra net monetary loss caused by
307 these waiting times was €700.840, which is an increase of 506% compared to 2019.

308
309 Several other models to study the effect of delayed surgery and to inform surgical recovery plans
310 have been developed. Degeling et al. for example,[55] developed a model to estimate the impact of
311 delayed cancer diagnosis and treatment on survival outcomes and healthcare costs based on a shift
312 in the cancer disease stage at treatment initiation. They showed that a conservative 3-month delay in
313 cancer diagnosis and treatment due to the COVID-19 pandemic, results in an excess health cost of
314 \$12 million in Australia over 5 years for the in 2020 diagnosed patients for 4 cancers. Gravesteijn et
315 al.[56] also developed a model that supports prioritization of care. They, however, focused on semi-
316 elective surgeries, including cardiothoracic, oncological and transplantation surgery, whereas we

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3 317 focused on elective surgeries. Needless to say that cancer patients and patients awaiting organ
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5 318 transplantation have a completely different profile as far as prognosis of their disease on the one
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7 319 hand and burden of awaiting treatment, on the other, is concerned. Furthermore, they used the
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9 320 global burden of disease by the WHO to estimate the QALY for 1/3 of the surgeries, and for the other
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11 321 2/3 they used estimates by an expert panel. Our quality of life data are based on literature data from
12
13 322 comparative studies using validated quality of life measures, which is in agreement with the ISPOR
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15 323 recommendation to use health-utility data collected from patients.[57] Wang et al.[58] developed a
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17 324 framework to model surgical backlog recovery. In contrast to our model, they did not include quality
18
19 325 of life assessment to guide prioritization of care. They used available resources and bed capacity that
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21 326 are adjustable to other contexts, aiding region-specific decision-making. The COVIDSurg
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23 327 Collaborative[2] and Brandman et al.[59] separately developed models to predict the size of the
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25 328 backlog and time needed to restore this backlog. Although these models are different from the
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27 329 present framework, combining both perspectives might result in a comprehensive context specific
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29 330 policy to clear the surgical backlog.
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38 332 The major strength of our approach is that the data used from literature are completely transparent
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40 333 in the online framework, and that it can easily be adapted according to local settings (e.g. regarding
41
42 334 operation times) and new available evidence. Our model was built with high-quality QoL- and cost
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44 335 data that were derived from randomised controlled trials or comparative studies. We had the unique
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46 336 opportunity to cross validate our results to a national study by the Dutch Institute for Public Health
47
48 337 and the Environment and empirical data from a large local hospital.[10] The concordance appeared
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50 338 to be very high with more than 75% overlap. Furthermore, by calculating the net monetary losses per
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52 339 week weighed by OR minute we were able to make a comparison between procedures and surgical
53
54 340 disciplines based on the surgery time. This provides new insights on how to allocate valuable surgery
55
56 341 time when comparing these operations, to maximize value.
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3 342 Some potential limitations should also be discussed. First, we used average data from literature
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5 343 rather than patient-level data, which could impact the applicability of our results to the individual
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7 344 patient. However, our goal was to develop a practical framework to support priority setting able to
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9 345 generalize and compare on department and surgery level instead. The model is therefore useful in
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11 346 general during the COVID-19 pandemic as well as for policy-making in striving for quality-driven
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14 347 healthcare.

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16 348 Second, we did not yet take into account other related factors such as ICU or personnel capacity, the
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18 349 number of beds available, the risk of exposing patients to perioperative COVID-19 infection, or
19
20 350 psychological consequences. This was outside the scope of this paper but can be added in a future
21
22 351 model, and of course these factors can be taken into account in the individual trade-off.

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25 352 Third, impact of waiting on medication costs (for example pain medication that patients need while
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27 353 waiting for surgery), could not be taken into account because they were either not reported in
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29 354 literature or not described in enough detail to be suitable for inclusion in the model. In order to be
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31 355 able to take medication costs into account, better reporting of cost data, i.e. categorization of cost
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33 356 data, in clinical studies is needed. Furthermore, it could be expected that some patients need extra
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35 357 home care or had a prolonged stay in a nursing home because they are waiting for surgery. These
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37 358 costs were not reported in literature and were therefore not included in the model. Consequently,
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39 359 the total cost presented are an underestimation of the real cost.

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43 360 Fourth, besides impact on quality of life, delayed surgery may have a variety of consequences
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45 361 regarding the deterioration of the disease ranging from 'no harm' (varices, inguinal hernia) to
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47 362 'complications' (easy or difficult to treat, medically or surgically: Crohn's disease, ulcerative colitis) to
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49 363 disease-related death. Currently, high-quality data regarding the consequences of the delay of
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51 364 surgery on deterioration are lacking and could therefore not be included in our model. Because of
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53 365 the elective nature of the included procedures, we believe that deterioration with high impact (like
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55 366 disease-related death) will be limited. However, if this COVID-19 pandemic will prove that delaying
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3 367 the included procedures do lead to high impact deterioration it is necessary to include the
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5 368 consequences of delaying surgery, the model can be adapted accordingly.
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7 369 Fifth, so far, we only modelled 13 elective surgical procedures whereas there are many more. Since
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9 370 we developed an online framework, new data can easily be added to inform future decision making,
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11 371 for example additional high quality data comparing surgery to watchful waiting or non-surgical care.
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13 372 Others can also provide us with relevant information on other procedures, which we will check on
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15 373 consistency and validity, before adding them to the online framework.
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17 374 Sixth, for some procedures no data on quality of life or costs were available in literature. The fact
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19 375 that no relevant data were retrieved from literature for sphincteroplasty , male sling procedure, and
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21 376 tension-free vaginal tape procedure illustrates how difficult it is, and will be, to calculate the added
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23 377 value of these procedures. It renders this type of surgery ‘vulnerable’ in strategic discussions, but
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25 378 also stimulates groups active in this complex field to come up with data in support of continuing this
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27 379 type of operations. We are, however, aware of research projects that will follow the patients
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29 380 currently ‘waiting’ due to the backlog of the pandemic.[60] Hopefully, these projects will provide us
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31 381 with more accurate data, which are critical to obtain reliable estimates.
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35 383 The ongoing pandemic is having a collateral damage effect on health care and the delivery of surgical
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37 384 care to millions of patients worldwide. This is an effect that most certainly will persist for years to
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39 385 come. It is to be expected that cancer and other acute surgery, if cancelled during the pandemic, will
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41 386 be prioritized in most settings, whereas the impact on other elective surgeries for benign conditions
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43 387 will be cumulative, adding to the existing waiting times. Governments and other policy makers will
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45 388 be requested to fund substantial increases in surgical volume to clear backlogs, and this framework
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47 389 may help them to prioritize on evidence regarding QoL and cost savings rather than on a mixture of
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49 390 numbers and expert opinion.
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51 391 When addressing the backlog of postponed elective surgeries, it is tempting to start with surgeries
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53 392 that cause a high net monetary loss when delayed on the one hand and have large volumes on the
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3 393 other. However, as we look at bariatric surgery, we see a discrepancy between population impact
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5 394 and net monetary loss per OR minute. Although bariatric surgery has one of the highest net
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7 395 monetary losses of all procedures described in this paper, it has the lowest impact on population
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9 396 level due to small volumes. Also, when resuming total knee and total hip replacement first, huge
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11 397 numbers of patients need to be operated taking a lot of valuable OR time, while for bariatric surgery
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13 398 only a small number of patients needs to be operated. Therefore, we would like to emphasize that
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15 399 objective measures are indispensable for fair and justifiable prioritization of surgeries, and that these
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17 400 choices are preferably based on the net monetary loss per OR minute. Such medical care
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19 401 prioritisation data may add to future discussions on “appropriate use” of health care budgets.
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25 403 In conclusion, our online framework can be used in deciding how to address the postponed elective
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27 404 surgeries after the COVID-19 pandemic. Furthermore, the model will also be useful during possible
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29 405 future repeated waves of COVID-19 or in the long-term as it provides relevant information regarding
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31 406 an efficient distribution of OR time.
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3 408 **Figure legends**
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7 410 Figure 1: Overview of the methods used. 1a: Loss in quality of life (QoL) due to delayed or postponed
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9 411 surgery was calculated by extracting the QoL before surgery from the QoL after surgery and
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11 412 multiplying this with the duration of the delay (one week in our analyses). 1b: The costs (in €)
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13 413 associated with waiting for surgery were calculated by extracting the average costs after surgery
14
15 414 from the average costs before surgery and multiplying this with the duration of the delay (one week
16
17 415 in our analyses). 1c: The net monetary loss (monetary measure to calculate the total societal loss of
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19 416 delaying surgery) was calculated by multiplying the loss in QoL by the willingness to pay (€ 20,000)
20
21 417 and adding the extra costs associated with waiting for surgery. The willingness to pay represents the
22
23 418 amount of money society is willing to pay for one year in full health. 1d: Surgery associated net
24
25 419 monetary loss per week divided by operating time. Relevant when trying to optimize the operating
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27 420 schedule. During a two hour surgery, also two operations of one hour could be performed. In other
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29 421 words, the two hour surgery needs to be associated with twice as much NML as the 1 hour surgeries
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31 422 to be as worthwhile to perform.
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39 424 Figure 2: Overview of results. 2a: Loss in quality of life (QoL) due to delayed or postponed surgery
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41 425 expressed as a utility score. A utility reflects QoL on a 0 to 1 scale, with 0 representing death and 1
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43 426 representing full health. 2b: Extra health care expenditure due to waiting for surgery. 2c: The net
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45 427 monetary loss combines QoL and costs due to waiting for surgery, it is therefore the total loss of
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47 428 waiting another week for surgery, expressed in monetary terms. 2d: Surgery associated net
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49 429 monetary loss per week divided by operating time (i.e. it reflects the total cost per week per OR
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51 430 minute).
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3 432 **Declarations**
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7 434 **Competing interests**
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9
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13
14 437 financial relationships with any organisations that might have an interest in the submitted work in
15
16 438 the previous three years; no other relationships or activities that could appear to have influenced the
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18 439 submitted work
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23 441 **Licence**
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41 449 **Contributors and sources**
42

43 450 **Authors:**
44

45 451 MR, SW, JG, HG, MS, and TG have contributed to the conception and design of the study. All authors
46
47 452 have contributed to the final design of the paper. Modelling was performed by SW, SM, RV, MS, and
48
49 453 TG. Model input and feedback was received from RvdP, BB, HG, and our collaborators (see below).
50
51 454 MR, SW, MS and TG drafted the manuscript. The online framework was developed by SW. All authors
52
53 455 have made contributions to the drafting and revising of the article. All authors have read, reviewed
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55 456 and approved the final version of the manuscript before submission.
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25
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27
28 470 responsibility for the integrity of the data and the accuracy of the data analysis. There was no
29
30 471 commercial involvement in the study.
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38 474 **Transparency**
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41 475 The lead authors affirm that the manuscript is an honest, accurate, and transparent account of the
42
43 476 study being reported; and that no important aspects of the study have been omitted.
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48 478 **Data availability statement**
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51 479 All data used in this study were derived from sources available in the public domain. For references
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53 480 please refer to Table 2 or the online tool: <https://stanwijn.shinyapps.io/priORitize/>
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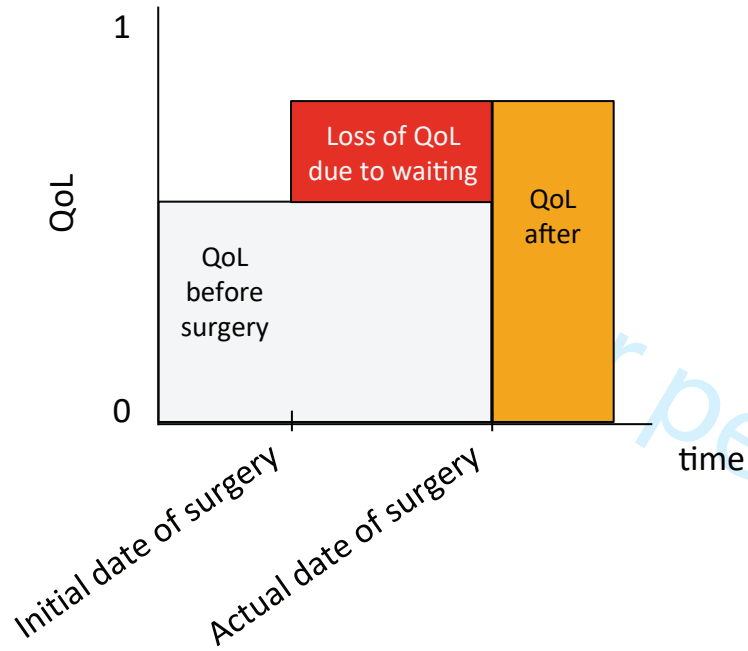
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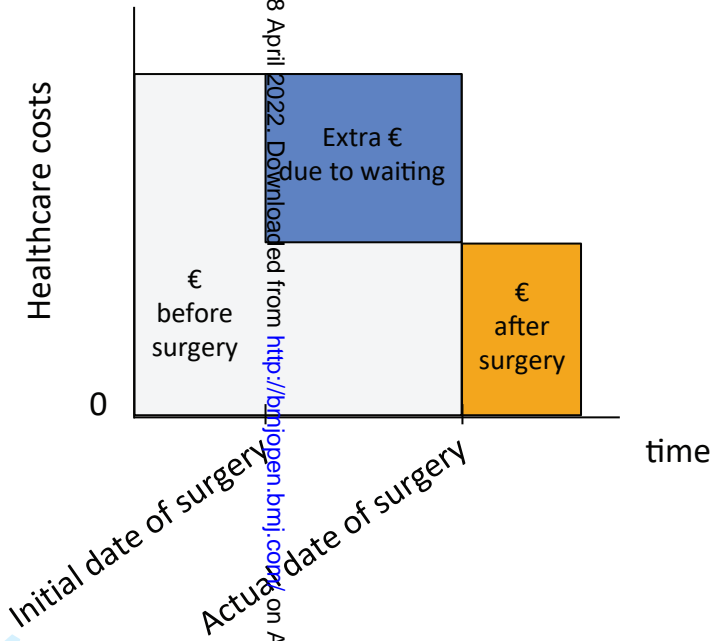
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Loss in quality of life due to delayed surgery



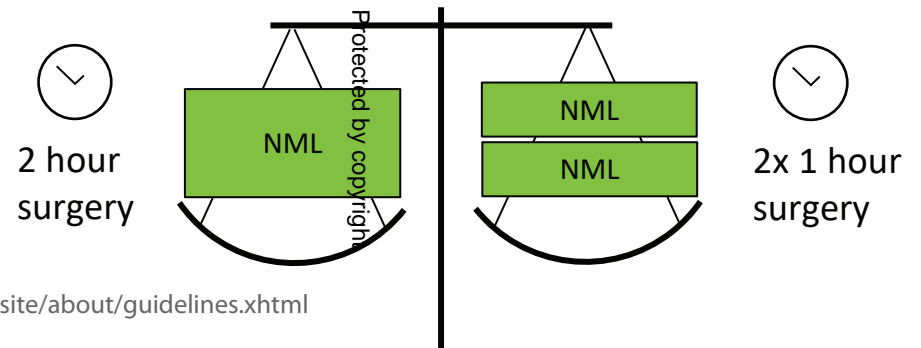
Cost associated with waiting for surgery



Surgery associated net monetary loss



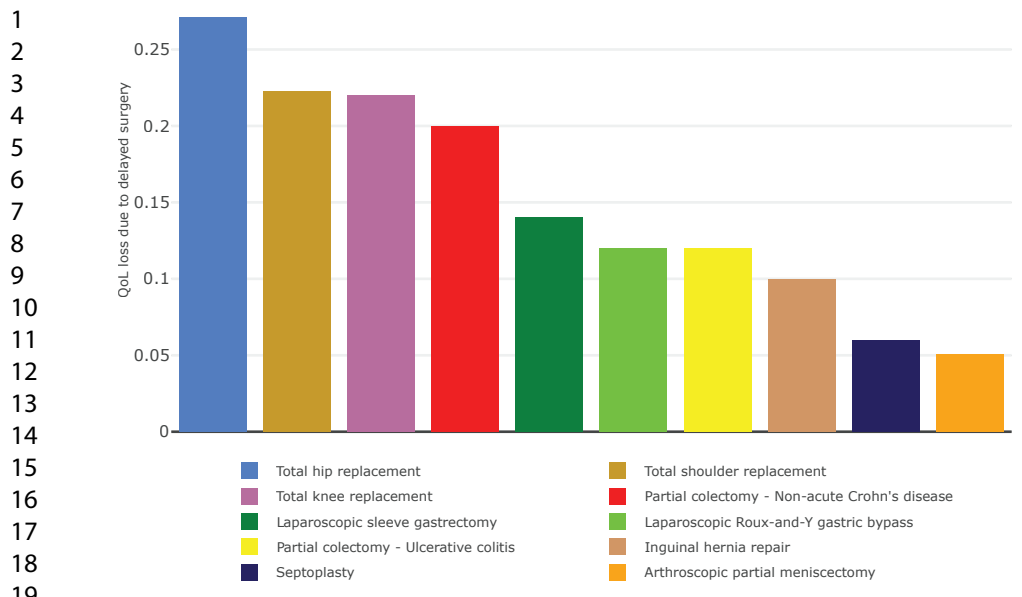
Net monetary loss weighted by operating time



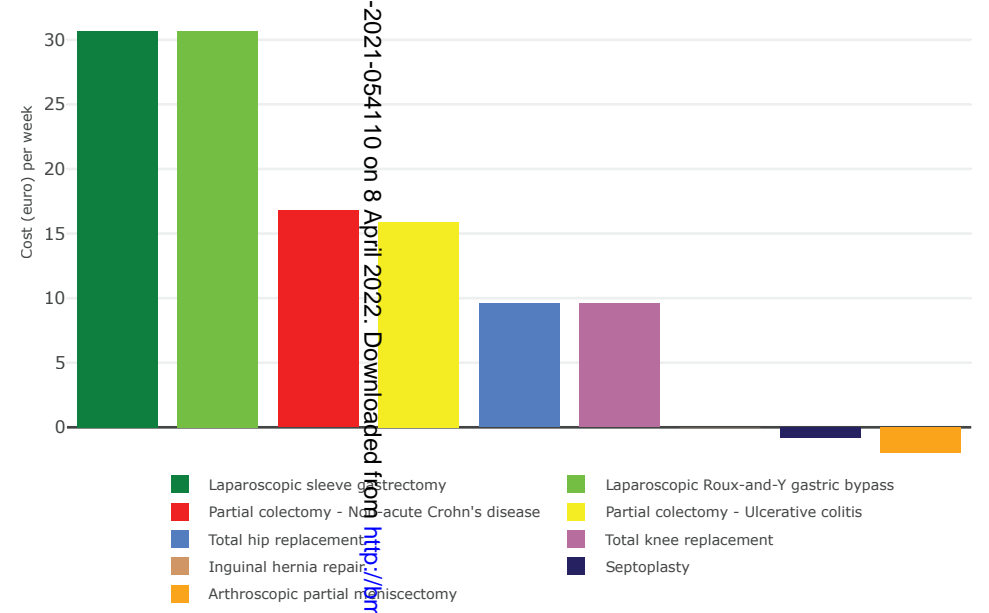
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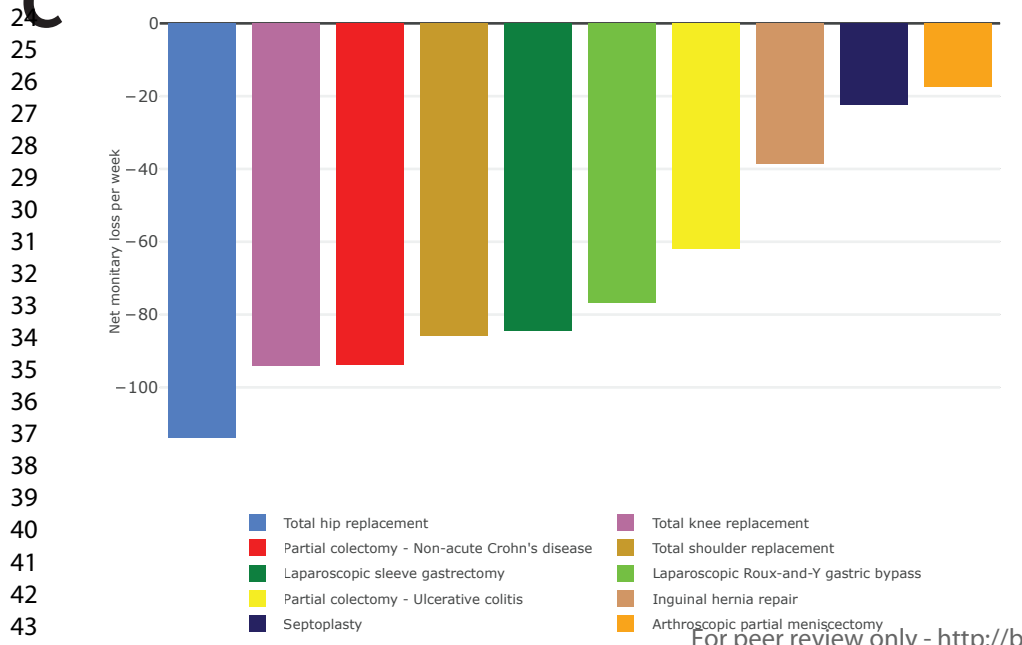
Loss in quality of life due to delayed surgery



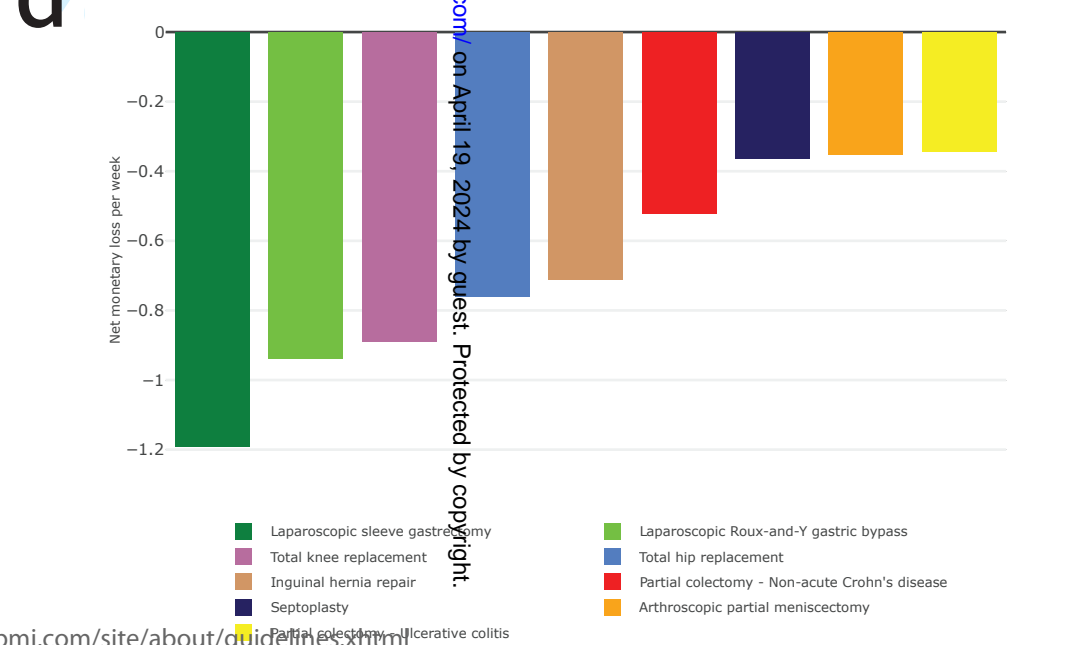
Cost associated with waiting for surgery (per week)



Surgery associated net monetary loss per week



Surgery associated net monetary loss weighted by operating time



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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)

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

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	€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.	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