# Resource requirements for reintroducing elective surgery in England during the COVID-19 pandemic: a modelling study

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## Abstract

*Background:* The response to COVID-19 has required cancellation of all but the most urgent surgical procedures, including cancer operations. The number of cancelled surgical procedures in the National Health Service (NHS) in England due to COVID-19, and how this would change over time once elective surgery was reintroduced, was modelled.

*Methods:* Modelling study using Hospital Episode Statistics (HES) data from 2014 to 2019. Using NHS England definitions, surgical procedures were grouped into four classes of urgency. Expected numbers of surgical procedures performed between 1st March 2020 and 28th February 2021 were modelled. The procedure deficit was estimated using multiple conservative assumptions and the reintroduction of elective surgery between 1st June 2020 and 28th February 2021. Costs of surgery were calculated using NHS reference costs, which are reported as millions (M) or billions (B) of Euros (€). Estimates are reported with 95% confidence intervals.

*Results:* 4 547 534 (3 318 195 - 6 250 771) patients with pooled mean age of 53.5 years were expected to undergo surgery in the NHS in England between 1st March 2020 and 28th February 2021. Due to COVID-19, 749 247 (95%CI: 513 564 to 1 077 448) surgical procedures were cancelled by 31st May 2020. Assuming a gradual reintroduction of elective surgery, 2 328 193 (1 483 834 – 3 450 043) patients will be awaiting surgery by 28th February 2021. The cost of delayed procedures is €5.32B (€3.08B - €8.20B). Safe delivery of surgery will require substantial extra resources, leading to additional costs of €519.14M (€438.20M - €632.75M).

*Conclusion:* Reintroduction of elective surgery during the pandemic response in NHS England will be associated with substantial treatment delays, and a large increase in costs. The challenges and costs of reintroduction of surgical care in other healthcare settings may differ.

## Introduction

The outbreak of novel coronavirus SARS-CoV-2 and the disease COVID-19, were first reported in December 2019 in Wuhan, China[1] and the World Health Organisation declared a global pandemic in March 2020. The healthcare response to the COVID-19 pandemic has required rapid changes to the provision of secondary healthcare services, including the creation of new hospitals.[2, 3] Critical care capacity has increased substantially in high income countries, requiring re-deployment of staff and equipment from other departments.[4] Surgical services represent a large portion of healthcare activity, accounting for 5 million hospital admissions to the United Kingdom (UK) National Health Service (NHS) every year.[5, 6] In March, National Health Service (NHS) England issued guidance to postpone non-urgent surgery from 15th April.[7] Only very urgent and emergency surgical treatments continued, with the cancellation of almost all planned cancer and non-cancer surgery.[8, 9] However, the number of surgical procedures cancelled during the pandemic response, and the excess of untreated surgical disease, remain unknown.[2, 8]

As the NHS response to the pandemic develops, there is a planned reintroduction of elective surgery with a particular focus on cancer surgery.[10] However, the risk of SARS-CoV-2 transmission within hospitals is a concern and further complicated by uncertain rates of asymptomatic infection in the general population (17% to 56%).[11, 12] Asymptomatic infection rates may be as high as 24% among healthcare staff.[13, 14] New procedures introduced to protect patients and staff from virus transmission have reduced capacity for surgery, as has a lack of appropriately trained staff requiring redeployment to other clinical areas.[2, 4] NHS plans to prevent in-hospital infection include preoperative patient screening, establishing 'clean' hospitals, routine staff testing and/or universal personal protective equipment (PPE).[8, 15] However, the optimum strategy, resource requirements and time-scale for reintroducing elective surgery remain uncertain.[15] Critical care utilisation remained high for patients with COVID-19 in some areas after the peak passed.[16] Capacity for surgical care remains limited in operating rooms, post-anaesthetic recovery units and critical care units whilst the incidence of serious postoperative complications amongst patients with COVID-19 is very high.[4, 17] A clear understanding of the number and type of overdue surgical procedures is urgently needed to inform national healthcare policies for reintroducing surgical services.

Hospital Episode Statistics (HES) data over five years from 2014 to 2019 were used to estimate the number of surgical procedures postponed in the NHS in England due to COVID-19. Multiple scenarios for the reintroduction of routine surgical activity over nine months, starting in June 2020, were modelled. Estimates of the cumulative national deficit of surgical procedures and the resource implications for 'catching up' with postponed procedures, in terms of hospital beds, critical care beds, PPE for staff, preoperative screening of patients for COVID-19, and the associated financial cost are presented.

## Methods

An unabridged description of the methods is provided in the appendix.

### *Data source*

Aggregated HES data for Admitted Patient Care (APC) from between 1st April 2014 and 31st March 2019 (https://digital.nhs.uk/data-and-information) were used. HES provide detailed data describing hospital care in England, including the type of surgical procedure categorised by an Office for Population Censuses Surveys Classification of Interventions and Procedures (OPCS) codes. All data used are freely available anonymised data and research ethics and information governance approvals were therefore not required.

### *Outcomes*

The primary outcome measure was the deficit of surgical activity, defined as the number of cancelled surgical procedures, attributable to the COVID-19 pandemic response. The secondary outcomes were the associated resource requirements, defined as: hospital bed days, number of critical care admissions, number of investigations for preoperative COVID-19 screening, the amount of PPE required for operating theatre staff and the additional financial cost.

### *Modelling analysis*

A statistical analysis plan was developed and published before data analysis took place.[18] R version 3.6.1 (R Core Team, Vienna, Austria) was used for data analysis. Surgical procedures were stratified according to a classification published by NHS England on 17th March 2020, which described operations that should be stopped or continued during the initial pandemic response.[7] Surgical procedures were divided into four classes of decreasing urgency: Class 1 – Emergency operations needed within 72 hours; Class 2 – Urgent surgery that can be deferred for up to 4 weeks; Class 3 – Semi-urgent surgery that can be delayed for up to 3 months; and Class 4 – Elective surgery that can be delayed for more than 3 months. A pre-specified, data-driven approach was used to identify emergency, urgent and elective surgical procedures based on waiting times and expert review of procedure coding (supplementary tables 1 and 2). The monthly volume of surgical activity that would have been expected had there not been a pandemic until 28th February 2021 was estimated, by calculating the annual

change in activity during the five-year period from 1st April 2014 to 31st March 2019, and extrapolated using a linear growth assumption. Estimations of monthly volume were calculated using NHS England Monthly Activity Returns, and the average age for each class of surgery was estimated.

*Surgical procedure volume*

The number of postponed or cancelled surgical procedures from the 1st March 2020 up to 1st June 2020 were estimated according to several assumptions. First, that class 1 (emergency) surgery would continue at the pre-pandemic rate. Second, that class 2 surgery would continue at a reduced rate. Four scenarios were calculated, where 20%, 40%, 60% and 80% of class 2 surgical procedures were assumed to have continued. Third, that 50% of class 3 and 4 procedures continued in March and then stopped completely in April and May, reflecting between-hospital heterogeneity in the timing of stoppage of surgery. The results were presented as the deficit of surgical procedures between 1st March and 31st May 2020 with a 95% confidence interval. Fourth, that widespread reintroduction of surgical activity would start from 1st June 2020 and continue to increase to pre-pandemic levels. For each of the four scenarios of class 2 procedures, a linear increase in activity over the three months from 1st June to 31st August 2020 was assumed, with class 3 and 4 surgical procedures remaining cancelled until 31st August. In the final model it was assumed that 80% of class 2 procedures continued. This analysis was repeated in an iterative fashion, by adding class 3 procedures on 1st September and class 4 procedures on 1st December. Fifth, that pre-pandemic levels of surgical activity would be reached by 28th February 2021 (supplementary figure 1). The estimated number of surgical procedures carried out each month between 1st March 2020 and 28th February 2021 and a rolling deficit of surgical activity compared to the expected volume of surgery according to the previous five-year average are presented. Assumptions about a second peak of COVID-19 were not included, and neither were assumptions regarding the impact of reduced operating theatre utilisation due to enhanced infection control procedures. A post-hoc sensitivity analysis was performed assuming that all classes of surgery restarted one the 1st June 2020 and increased linearly over a 6 month period.

*Hospital admissions*

The total number of bed-days, weighted by procedure frequency, were calculated by multiplying the median length of stay by the number of inpatient admissions. The proportion of patients that would require postoperative critical care were estimated using a conservative assumption of 1% of patients undergoing inpatient surgery, and 4% of those undergoing emergency surgery.[19-21]

*Preoperative screening tests*

Preoperative COVID-19 screening requirements were modelled according to three scenarios. First, all patients would have two outpatient preoperative COVID-19 Polymerase Chain Reaction (PCR) tests. Second, all patients would have one outpatient and one inpatient preoperative SARS-CoV-2 PCR tests, requiring an additional day in hospital for isolation. Third, all patients would have one outpatient and one inpatient preoperative SARS-CoV-2 PCR tests, and patients undergoing class 1 (emergency) thoracic, cardiac or abdominal procedures would also have a computed tomography scan of the chest, in line with guidance from the Royal College of Radiologists.[22, 23]

*Personal protective equipment*

The amount of PPE required in operating theatres was estimated according to two scenarios.[24] First, that eight staff members would be present for every procedure (two surgeons, two anaesthetists, one operating department practitioner and three scrub staff). Second, that four staff members would be present for every procedure (one surgeon, one anaesthetist, one operating department practitioner and one scrub staff), each requiring an FFP3 mask, a fluid repellent gown, two pairs of gloves and eye protection.

*Estimated financial cost*

The estimated financial cost of reintroducing surgical activity was divided into three areas: the cost of the surgical procedure; the cost of preoperative COVID-19 screening arrangements; and, the cost of PPE required. The total cost of reintroducing surgical activity from 1st June 2020 and the total deficit of surgical procedures on 28th February 2021 was estimated by combining these. Costs were calculated in Great British Pounds (£) and are presented in Euros (€) based on the average exchange rate reported by OANDA on the 1st July 2020 (£1 = €1.09766). Costs of millions (M) and billions (B) are reported as whole amounts,

rounded to one decimal place. The total costs of surgical procedures was calculated by matching the OPCS v4.7 code with the Health Resource Group coding and summing the associated procedure cost according to the national schedule of NHS costs in 2015.[5, 25] The costs of screening tests were calculated according to £19 (€20.86) per SARS-CoV-2 PCR and £69 (€75.74) per CT scan and a range of between £222 (€243.68) and £346 (€379.79) per additional bed day.[26-28] The costs of PPE was calculated as £2.90 (€3.18) per FFP3 mask, £14.90 (€16.36) per 100 gloves, £3 (€3.29) per fluid resistant gown and £2.90 (€3.18) per piece of eye protection.[28, 29]

**Results**

Some 1073 OPCS codes for Class 1 – 4 surgical procedures, representing a total of 22 513 872 surgical admissions between 1st April 2014 and 31st March 2019 (Figure 1). The monthly median number of procedures was 382 768 (Interquartile range [IQR]: 22 890) (supplementary table 3). If growth in the number of surgical procedures had continued according to a pre-pandemic trajectory, 4 547 534 (95%CI: 3 318 195 to 6 250 771) would have been performed between 1st March 2020 and 28th February 2021 (supplementary table 4). Patients aged over 60 years accounted for 32.7% of class 1, 43.9% of class 2, 53.7% of class 3 and 45.6% of class 4 surgical activity (supplementary table 5).

*Surgical procedure volume*

Between 1st March and 31st May 2020, 749 247 (95%CI: 513 564 to 1 077 448) surgical procedures will have been cancelled in comparison with observed pre-pandemic levels of activity (supplementary table 6). The widespread reintroduction of class 2 surgical activity from 31st May 2020, was modelled for four scenarios of incrementally increasing activity (20% - 80%) that would reach pre-pandemic levels by 31st August 2020 (supplementary table 7). Even if class 2 - 4 surgical procedures are reintroduced in a stepwise fashion between 1st June 2020 and 28th February 2021 to reach the predicted pre-pandemic level of activity, the number of cancelled surgical procedures would be 2 328 193 (95% CI: 1 483 834 to 3 450 043) procedures (table 1, figures 2-3). In a post-hoc sensitivity analysis assuming all classes of surgery restarted on 1st June and took six months to get to normal capacity, the number of cancelled surgical procedures was estimated to be 1 364 586 (916 768 to 1 994 381) (supplementary table 11).

*Hospital admissions*

The total bed days associated with the deficit of surgical activity on 31st May 2020 is 973 006 (95%CI: 623 700 to 1 423 014) days (supplementary table 8). If widespread reintroduction of surgical activity occurs from 1st June 2020, the total number of bed days associated with the cumulative deficit of surgical activity up to 28th February 2021 is 3 337 706 (95%CI: 1 997 510 to 4 995 117) days (supplementary table 8). The total number of critical care admissions associated with the deficit of surgical activity on 31st May 2020 is 2 474 (95%CI: 1 536 to 3 650) (supplementary table 8). If widespread reintroduction of surgical activity occurs from 1st

June 2020, the estimated total number of critical care admissions associated with the cumulative deficit of surgery up to 28th February 2021 will be 8 769 admissions (95%CI: 5 103 to 13 207) (supplementary table 8).

*Preoperative screening tests*

The estimated resource requirement for preoperative COVID-19 screening associated with the deficit of surgical activity on 31st May 2020 include: 1 390 104 (95%CI: 939 958 to 2 018 502) SARS-CoV-2 PCR tests and 247 321 (95%CI: 153 633 to 365 080) bed days for preoperative isolation. The screening resource requirements associated with the reintroduction of surgical activity from 1st June 2020 is provided in table 2.

*Personal protective equipment*

The estimated amount of PPE associated with the deficit of surgical activity on 31st May 2020 is 11 120 832 (95% CI: 7 519 664 to 16 148 016) items, assuming four persons per theatre, and 22 241 664 (95% CI: 15 039 328 to 32 296 032) items assuming eight persons pre theatre. The estimated total amount of PPE associated with the cumulative deficit of surgical activity by 28th February 2021 is between 37 251 088 (95%CI: 23 741 344 to 55 200 672) items, assuming four persons per theatre and 74 502 176 items (95%CI: 47 482 688 to 110 401 344) assuming eight persons per theatre (supplementary table 8).

*Financial cost*

The procedure cost for the deficit of surgical activity on 31st May 2020 is €1.5B (95%CI: €923.0M to €2.2B) (table 2 and supplementary table 10). If elective surgery recommences between 1st June 2020 and 28th February, the total costs associated with performing reintroduced surgery, including the costs of the procedure, PPE and screening, are between €5.4B (95%CI: €4.4B to €6.7B) and €5.7B (95%CI: €4.6B to €7.0B) (supplementary table 9). The total cost of cancelled operations by 28th February 2021, including the costs of the procedure, PPE and screening tests, are between €5.7B (95%CI: €3.4B to €8.7B) and €6.0B (95%CI: €3.5B to €9.1B) (supplementary table 10).

An unabridged description of the results is provided in the appendix.

**Discussion**

The principal finding of this study is that, without a substantial increase in capacity, accumulated delays in surgical care will lead to a backlog of more than two million overdue or cancelled surgical procedures in the NHS in England by 28th February 2021. This is equivalent to 45% of the total number of surgical procedures performed in England each year before the COVID-19 pandemic, and is larger than the existing waiting list to start surgical treatment in March 2020, which already stood at over 1.8 million patients.[30] The cost of clearing this post-pandemic waiting list is in excess of €5 billion, or 4.2% of the total NHS England budget.[31] Additional costs of delivering surgical services under strict infection control procedures exceed €500 million, and include personal protective equipment, preoperative screening and extra bed-days in hospital. No attempt was made to model the reduced operating theatre utilisation efficiency, suggesting the true excess cost may be far greater. Nor does this estimate account for additional costs of contracts with non-NHS providers, or the costs of postoperative complications among surgical patients with COVID-19.[4, 17] In order to reduce the size of any future backlog of overdue surgery, elective surgical services would need to be reintroduced at the earliest opportunity and at the maximum capacity possible. Whether this can be achieved safely remains unclear.[15]

Postoperative mortality is much higher in patients with COVID-19 infection, compared to the expected pre-pandemic rate.[17] An international cohort study of more than 1000 patients with COVID-19 found the incidence of postoperative mortality was more than one in four patients, compared to an expected mortality rate of 1 in 30 patients undergoing emergency surgery.[17] This will inevitably lead to higher resource use, longer in-patient lengths of stay and greater financial costs. Furthermore, emerging data from the UK suggests that as many as one in twelve healthcare workers had asymptomatic infection during the first peak of the pandemic, and were at risk of transmitting the virus to other staff and patients.[14] Consequently, many surgeons may choose to avoid surgery in patients with COVID-19 infection, to reduce the active reservoir inside the hospital and to mitigate the higher-risk of postoperative mortality. When surgery does go ahead, the benefits must be weighed against the potential harm of bringing vulnerable patients into contact with SARS-CoV-2 and the potential risks to staff members. It is likely that preoperative screening for the virus and PPE for healthcare workers will become universal. It is estimated that by February 2021, over 160 000 SARS-CoV-2 PCR

tests will be required every week for preoperative screening alone. Permanent infrastructure for testing will need to be included in strategic plans for pathology services to support elective surgery. There are no national data regarding the use of protective equipment at individual institutions. However, many societies have exercised caution and have advocated for the deployment of full PPE for all high risk procedures and examinations, including all aerosol generating procedures.[24]

There are no published data on the rate of cancellation of surgery within the NHS in England during the COVID-19 pandemic response, of which we are aware. However, the results of this analysis are consistent with data from an international survey, which reported that the majority of both urgent cancer and non-cancer surgery were postponed during the peak of the pandemic.[9] This analysis provides early evidence that disruption to surgical care has been widespread and reintroduction of this care will have substantial resource requirements that will differ between healthcare settings. Delays to the re-introduction of surgical procedures may result in increased secondary morbidity and mortality, not directly attributable to COVID-19 infection, but due to increased volume of undiagnosed surgical disease and delays to curative therapy.[2] If delays in surgical care result in higher incidence of more advanced disease, it is likely that postoperative morbidity and mortality will also increase, as well as critical care bed utilisation and hospital length of stay. Strategies for undertaking safe surgery after the pandemic, during a prolonged pandemic response, or if COVID-19 becomes endemic, include reorganisation of referral pathways, restructuring of the surgical workforce, dedicated surgical critical care resources, isolated 'cold' hospitals and prioritisation of certain patient groups.[2] If second or subsequent peaks of COVID-19 occur, it is likely surgical services will again be curtailed, with further increases in the number of cancelled procedures. NHS leaders should make plans for the future continuity of surgical care.

This analysis has several strengths. Robust national data were analysed that describe the whole healthcare setting of a single country according to a prospectively published statistical analysis plan. Conservative estimates are purposely provided of estimates of procedure volume and associated resource requirements. Procedures are reported at the admission level, rather than the episode level, which will likely underestimate the volume of surgery. Assignment to urgency class based on mean wait time may lead to some inappropriate

classification of individual procedures but was the only feasible option. Multiple sources were used to calculate postoperative critical care admission, which did not include preoperative admission, nor increased critical care utilisation for patients with COVID-19. Estimates of PPE only include usage in operating theatre, but not on postoperative wards or in clinics. Cost estimates do not take account of potential future reorganisation of care pathways, the use of 'hot' and 'cold' sites or use of private sector hospitals. This analysis also has limitations. A series of assumptions were made based on NHS England guidance, which were applied to a series of plausible scenarios regarding the continuation of surgical activity during the pandemic.[7, 10] However, the reality of the volume, type and timing of continuation and reintroduction of surgery may differ from these models. The models implemented in this analysis are highly sensitive to the rate and timing of the resumption of surgical care, as evidenced by the much lower cumulative deficit in the sensitivity analysis. It will only be possible to test this in retrospect once actual numbers of procedures carried out are published. Our analysis does not account for lower throughput of surgery due to stricter infection control procedures or a potential second peak of COVID-19.[32] Further research is urgently needed to address these issues. It is likely that the volume of emergency surgery that has continued during the pandemic is lower than pre-pandemic levels, perhaps due to patients avoiding hospital or clinicians using alternative management strategies.[33] The age distribution of the surgical population is skewed.[6] However, due to limitations of the data source, age adjustment in the analysis was not possible. It is likely that, unfortunately, some patients waiting for surgery will have died while waiting to have their surgery. The numbers of these cases are unknown, and it was not possible to account for these in the analysis. It is likely that patients who have delayed care will have higher care needs and associated financial costs. There will also be higher human costs in terms of chronic symptoms and disability that it was not possible to account for in this analysis.[2] This analysis will be updated as new data become available.

In conclusion, accumulated delays in surgical care due to COVID-19 will lead to a backlog of more than two million overdue or cancelled surgical procedures in the NHS in England by 28th February 2021. These delays in care are likely to be associated with increased mortality. The procedure cost of clearing this waiting list is more than €5.3 billion, with additional costs of at least €440 million for personal protective equipment and preoperative screening during

the pandemic. Further research is needed to provide regular reports of NHS surgical activity across the United Kingdom, to support strategic planning of the re-introduction of elective surgery nationwide.

## Contributions

AF, TD and TA were responsible for study design. RL, SH, TD, YW and AF were responsible for data collection. AF and TA were responsible for data analysis. AF, TD, RP and TA were responsible for data interpretation. TA wrote the first draft of the manuscript. All authors revised the manuscript for important intellectual content and approved the final version.

## Declarations of interest

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## Data sharing

The data source is freely available online.

## Preregistration

A statistical analysis plan was published on our website prior to starting the analysis (doi: 10.17636/64678).

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## Tables

| Class of Surgery | Mar | April | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Jan. | Feb. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Procedures carried out each month** | | | | | | | | | | | | |
| **Class 1** | 72 999 (69 230 to 76 769) | 67 776 (63 324 to 72 227) | 70 844 (66 191 to 75 497) | 69 027 (64 493 to 73 561) | 70 502 (65 871 to 75 133) | 67 738 (63 289 to 72 187) | 68 575 (64 071 to 73 079) | 72 048 (67 316 to 76 781) | 71 308 (66 624 to 75 991) | 72 665 (67 892 to 77 438) | 72 593 (67 825 to 77 361) | 66 472 (62 106 to 70 838) |
| **Class 2** | 28 232 (23 362 to 34 218) | 26 566 (21 365 to 33 429) | 27 629 (22 220 to 34 767) | 35 770 (28 767 to 45 010) | 35 854 (28 835 to 45 117) | 33 825 (27 203 to 42 563) | 34 965 (28 120 to 43 998) | 36 731 (29 540 to 46 220) | 36 542 (29 388 to 45 982) | 31 840 (25 607 to 40 066) | 35 094 (28 223 to 44 160) | 33 840 (27 215 to 42 582) |
| **Class 3** | 84 128 (69 109 to 110 982) | 0 (0 to 0) | 0 (0 to 0) | 0 (0 to 0) | 0 (0 to 0) | 0 (0 to 0) | 37 557 (30 940 to 52 842) | 78 907 (65 004 to 111 020) | 11 7752 (97 005 to 165 674) | 136 801 (112 698 to 192 476) | 150 781 (124 216 to 212 146) | 145 392 (119 776 to 204 563) |
| **Class 4** | 58 018 (30 779 to 86 570) | 0 (0 to 0) | 0 (0 to 0) | 0 (0 to 0) | 0 (0 to 0) | 0 (0 to 0) | 0 (0 to 0) | 0 (0 to 0) | 0 (0 to 0) | 28 346 (13 346 to 44 249) | 62 486 (29 419 to 97 542) | 90 380 (42 551 to 141 083) |
| **Total** | 243 377 (192 480 to 308 539) | 94 342 (84 689 to 105 656) | 98 473 (88 411 to 110 264) | 104 797 (93 260 to 118 571) | 106 356 (94 706 to 120 250) | 101 563 (90 492 to 114 750) | 141 097 (123 131 to 169 919) | 18 7686 (161 860 to 234 021) | 225 602 (193 017 to 287 647) | 269 652 (219 543 to 354 229) | 320 954 (249 683 to 431 209) | 336 084 (251 648 to 459 066) |
| **Cumulative deficit of cancelled surgical procedures** | | | | | | | | | | | | |
| **Class 1** | 0 (0 to 0) | 0 (0 to 0) | 0 (0 to 0) | 0 (0 to 0) | 0 (0 to 0) | 0 (0 to 0) | 0 (0 to 0) | 0 (0 to 0) | 0 (0 to 0) | 0 (0 to 0) | 0 (0 to 0) | 0 (0 to 0) |
| **Class 2** | 7 058 (5 840 to 8 555) | 13 699 (11 181 to 16 912) | 20 606 (16 736 to 25 604) | 25 972 (21 051 to 32 356) | 29 557 (23 934 to 36 867) | 31 248 (25 295 to 38 996) | 31 248 (25 295 to 38 996) | 31 248 (25 295 to 38 996) | 31 248 (25 295 to 38 996) | 31 248 (25 294 to 38 996) | 31 248 (25 295 to 38 996) | 31 248 (25 295 to 38 996) |
| **Class 3** | 84 127 (69 109 to 110 982) | 226 800 (186 645 to 311 721) | 375 186 (308 887 to 520 497) | 528 870 (435 494 to 736 727) | 682 917 (562 400 to 953 468) | 828 246 (682 124 to 1 157 943) | 940 917 (774 943 to 1 316 468) | 1 019 824 (839 948 to 1 427 489) | 1 059 074 (872 283 to 1 482 714) | 1 059 074 (872 283 to 1 482 714) | 1 059 074 (872 283 to 1 482 714) | 1 059 074 (872 283 to 1 482 714) |
| **Class 4** | 58 019 (30 779 to 86 569) | 176 272 (86 453 to 271 164) | 299 260 (144 356 to 463 150) | 426 639 (204 326 to 661 990) | 554 319 (264 438 to 861 300) | 674 773 (321 148 to 1 049 330) | 799 287 (379 770 to 1 243 698) | 930 089 (441 352 to 1 447 881) | 1 060 218 (502 617 to 1 651 014) | 1 145 258 (542 653 to 1 783 761) | 1 207 745 (572 072 to 1 881 304) | 1 237 871 (586 256 to 1 928 332) |
| **Total** | 149 204 (105 728 to 206 106) | 416 771 (284 279 to 599 797) | 695 052 (469 979 to 1 009 251) | 981 481 (660 871 to 1 431 073) | 1 266 793 (850 772 to 1 851 635) | 1 534 267 (1 028 567 to 2 246 269) | 1 771 452 (1 180 008 to 2 599 162) | 1 981 161 (1 306 595 to 2 914 366) | 2 150 540 (1 400 195 to 3 172 724) | 2 235 580 (1 440 230 to 3 305 471) | 2 298 067 (1 469 650 to 3 403 014) | 2 328 193 (1 483 834 to 3 450 042) |

**Table 1.** Model for reintroduction of surgical activity between 1st March 2020 and 28th February 2021, assuming: continued class 1 (emergency) activity at pre-pandemic levels; continued class 2 (urgent) activity at 80% of pre-pandemic levels and increasing on 1st June to reach pre-pandemic levels by 31St August; reintroduction of class 3 activity on 1st September and reaching pre-pandemic levels by 31st November; and reintroducing class 4 activity on 30th November and reaching pre-pandemic levels by 28th February 2021. The top panel shows the number of procedures carried out in each month between 1st March 2020 and 28th February 2021. The bottom panel shows the cumulative deficit of surgical activity on the last day of each month. Numbers are presented as predicted time-weighted average with 95% confidence intervals.

| Item | Mar | April | May | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. | Jan. | Feb. | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Admissions for surgery** | 243 377 (192 480 to 308 539) | 94 342 (84 689 to 105 656) | 98 473 (88 411 to 110 264) | 104 797 (93 260 to 118 571) | 106 356 (94 706 to 120 250) | 101 563 (904 92 to 114 750) | 141 097 (123 131 to 169 919) | 187 686 (161 860 to 234 021) | 225 602 (193 017 to 287 647) | 269 652 (219 543 to 354 229) | 320 954 (249 683 to 431 209) | 336 084 (251 648 to 459 066) | 2 237 041 (1 848 760 to 2 822 676 |
| **Bed days** | 674 874 (575 731 to 792 195) | 454 047 (412 743 to 500 865) | 474 136 (431 057 to 522 959) | 473 547 (429 306 to 524 105) | 487 702 (441 725 to 540 388) | 472 336 (427 424 to 523 916) | 524 948 (471 086 to 595 008) | 592 159 (528 411 to 682 305) | 627 556 (557 139 to 733 557) | 687 956 (590 698 to 825 927) | 771 877 (638 708 to 951 627) | 777 409 (622 654 to 978 739) | 7 018 546 (6 126 681 to 8 171 592) |
| **Day cases** | 122 966 (94 418 to 161 716) | 27 599 (24 051 to 31 982) | 28 779 (25 084 to 33 341) | 29 790 (25 847 to 34 687) | 31 036 (26 890 to 36 196) | 30 387 (26 292 to 35 490) | 60 454 (51 054 to 77 524) | 93 417 (78 272 to 123 520) | 122 613 (102 308 to 164 665) | 149 468 (119 396 to 204 936) | 179 135 (137 641 to 249 128) | 187 392 (139 279 to 263 472) | 1 063 035 (850 532 to 1 416 657) |
| **Critical care admissions** | 2 933 (2 621 to 3 286) | 2 272 (2 106 to 2 446) | 2 374 (2 203 to 2 557) | 2 331 (2 158 to 2 515) | 2 389 (2 209 to 2 574) | 2 300 (2 129 to 2 481) | 2 429 (2 239 to 2 655) | 2 650 (2 432 to 2 923) | 2 719 (2 485 to 3 030) | 2 925 (2 610 to 3 326) | 3 137 (2 730 to 3 654) | 3 063 (2 594 to 3 633) | 31 522 (28 516 to 35 080) |
| **SARS-CoV 2 PCR test** | 486 754 (384 960 to 617 078) | 188 684 (169 378 to 211 312) | 196 946 (176 822 to 220 528) | 198 862 (177 890 to 223 638) | 205 542 (183 646 to 231 478) | 199 744 (178 262 to 225 242) | 282 194 (246 262 to 339 838) | 375 372 (323 720 to 468 042) | 451 204 (386 034 to 575 294) | 539 304 (439 088 to 708 458) | 641 908 (499 364 to 862 418) | 672 168 (503 296 to 918 132) | 4 438 682 (3 668 722 to 5 601 458) |
| **CT scans** | 23 609 (22 390 to 24 829) | 21 920 (20 480 to 23 360) | 22 912 (21 407 to 24 417) | 22 325 (20 858 to 23 791) | 22 802 (21 304 to 24 299) | 21 908 (20 469 to 23 347) | 22 178 (20 722 to 23 635) | 23 302 (21 771 to 24 832) | 23 062 (21 547 to 24 577) | 23 501 (21 958 to 25 045) | 23 478 (21 936 to 25 020) | 21 498 (20 086 to 22 910) | 272 495 (254 928 to 290 062) |
| **Excess bed days for screening** | 120 411 (98 062 to 146 823) | 66 743 (60 638 to 73 674) | 69 694 (63 327 to 76 923) | 69 641 (63 098 to 77 132) | 71 735 (64 933 to 79 543) | 69 485 (62 839 to 77 131) | 80 643 (72 077 to 92 395) | 94 269 (83 588 to 110 501) | 102 989 (90 709 to 122 982) | 120 184 (100 148 to 149 293) | 141 819 (112 041 to 182 081) | 148 692 (112 369 to 195 594) | 1 156 305 (983 828 to 1 384 071) |
| **Excess Cost (low estimate) [€]** | 54 897 505 (44 388 547 to 67 789 402) | 27 137 237 (24 597 823 to 30 040 329) | 28 335 070 (25 686 881 to 31 361 902) | 28 371 282 (25 641 573 to 31 517 445) | 29 243 677 (26 403 552 to 32 526 097) | 28 344 671 (25 567 281 to 31 561 806) | 35 109 913 (31 157 850 to 40 898 765) | 43 065 251 (37 824 494 to 51 661 456) | 48 874 793 (42 585 392 to 59 920 575) | 57 399 954 (47 507 340 to 72 869 753) | 67 680 040 (53 346 781 to 88 375 183) | 70 682 636 (53 478 553 to 94 228 594) | 519 142 029 (438 186 067 to 632 751 307) |
| **Excess cost (high estimate) [€]** | 84 902 651 (68 504 200 to 105 034 965) | 41 499 628 (37 589 217 to 45 979 176) | 43 330 333 (39 252 569 to 48 000 654) | 43 412 945 (39 205 926 to 48 271 732) | 44 757 116 (40 378 672 to 49 827 770) | 43 389 728 (39 106 854 to 48 360 778) | 53 979 996 (47 856 936 to 62 980 941) | 66 396 479 (58 257 093 to 79 794 253) | 75 514 183 (65 730 293 to 92 752 375) | 88 844 187 (73 421 155 to 113 007 764) | 104 939 044 (82 565 354 to 137 282 626) | 109 723 690 (82 851 740 to 146 533 739) | 800 689 980 (674 720 009 to 977 826 773) |

**Table 2.** Resource requirements each month for reintroduction of surgical activity from 1st March 2020 until 28th February 2021. Total number of procedures is presented as a time-weighted average with 95% confidence intervals derived from a linear growth model at procedure group level. Costs are presented in pounds sterling and include only excess costs associated with specific measures required for surgical time. Low estimate: four members of staff in personal

protective equipment, bed day cost of £222 (€243.68). High estimate: eight members of staff in personal protective equipment, bed day cost of £346 (€379.79). A complete breakdown of costs is in supplementary table 9. Costs are provided in Euros (€).