Original article

Elective surgery cancellations due to the COVID-19 pandemic: global predictive modelling to inform surgical recovery plans

COVIDSurg Collaborative*

Correspondence to: Dr D. Nepogodiev, National Institute for Health Research Global Health Research Unit on Global Surgery, Heritage Building, University of Birmingham, Mindelsohn Way, Birmingham B15 2TH, UK (e-mail: dnepogodiev@doctors.org.uk)

Background: **The COVID-19 pandemic has disrupted routine hospital services globally. This study estimated the total number of adult elective operations that would be cancelled worldwide during the 12 weeks of peak disruption due to COVID-19.**

Methods: **A global expert response study was conducted to elicit projections for the proportion of elective surgery that would be cancelled or postponed during the 12 weeks of peak disruption. A Bayesian β-regression model was used to estimate 12-week cancellation rates for 190 countries. Elective surgical case-mix data, stratified by specialty and indication (surgery for cancer *versus* benign disease), were determined. This case mix was applied to country-level surgical volumes. The 12-week cancellation rates were then applied to these figures to calculate the total number of cancelled operations.**

Results: **The best estimate was that 28 404 603 operations would be cancelled or postponed during the peak 12 weeks of disruption due to COVID-19 (2 367 050 operations per week). Most would be operations for benign disease (90·2 per cent, 25 638 922 of 28 404 603). The overall 12-week cancellation rate would be 72·3 per cent. Globally, 81·7 per cent of operations for benign conditions (25 638 922 of 31 378 062), 37·7 per cent of cancer operations (2 324 070 of 6 162 311) and 25·4 per cent of elective caesarean sections (441 611 of 1 735 483) would be cancelled or postponed. If countries increased their normal surgical volume by 20 per cent after the pandemic, it would take a median of 45 weeks to clear the backlog of operations resulting from COVID-19 disruption.**

Conclusion: **A very large number of operations will be cancelled or postponed owing to disruption caused by COVID-19. Governments should mitigate against this major burden on patients by developing recovery plans and implementing strategies to restore surgical activity safely.**

*Members of the COVIDSurg Collaborative are co-authors of this study and are listed in *Appendix S1* (supporting information)

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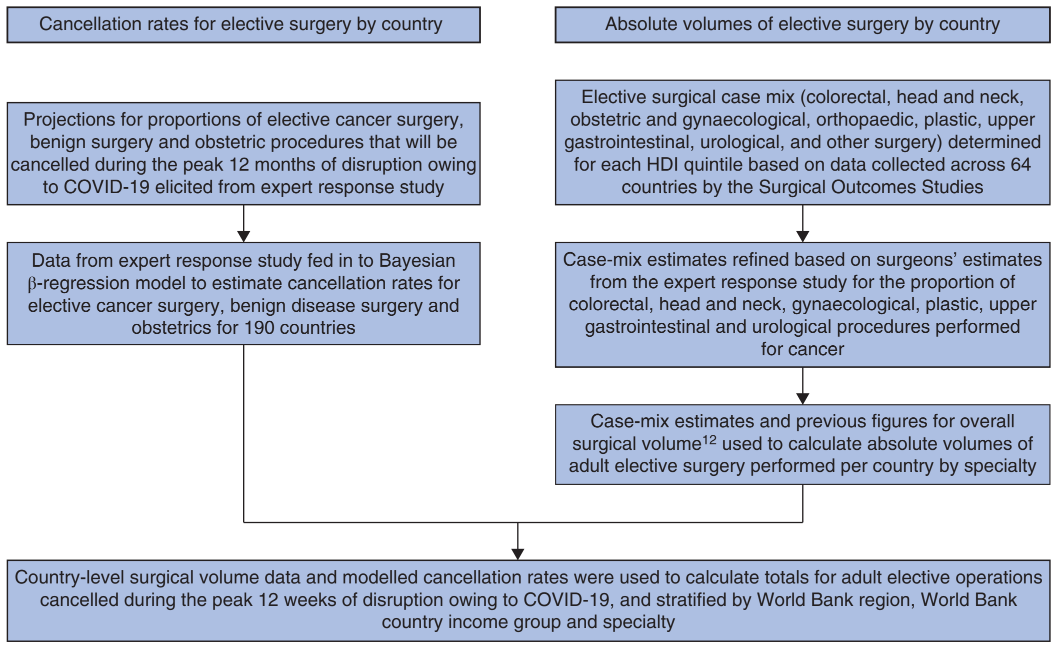
Introduction

The COVID-19 pandemic has led to major disruption of routine hospital services globally[1]. During the pandemic hospitals have reduced elective surgery in the interests of patient safety and supporting the wider response[2–4]. Reducing elective activities protects patients from in-hospital viral transmission and associated postoperative pulmonary complications. This preserves personal protective equipment supplies to be prioritized for the care of patients with COVID-19, and releases ward and critical care beds for surges in such patients. It also enables recovery areas in theatre suites to be repurposed as overflow ICUs. Surgeons and theatres teams may be redeployed to support other critical areas of the hospital.

Cancelling elective surgery on this scale will have a substantial impact on patients and cumulative, potentially devastating, consequences for health systems worldwide[5]. Delaying time-sensitive elective operations, such as cancer or transplant surgery, may lead to deteriorating health, worsening quality of life, and unnecessary deaths[6–8]. When hospitals resume elective activities, patients are likely to be prioritized by clinical urgency[9], resulting in lengthening delays for patients with benign but potentially disabling conditions where there may be less of a perceived time impact. This will lead to a deterioration in population health, productivity and a substantial societal cost.

Worldwide cancellations in elective surgery are currently unquantified[10,11]. Few countries have access to real-time

Fig. 1 Flow chart of methodology



HDI, Human Development Index.

data, and even those that do may experience delays in this information being released owing to pressures on health systems. Estimating country-level estimates will provide the best possible baseline data to inform planning for post-pandemic surgical recovery. This study aimed to estimate the total number of elective operations that would be cancelled or postponed worldwide during the 12 weeks of peak disruption of hospital services owing to COVID-19.

Methods

The study methodology is summarized in *Fig. 1*. First, an expert response study was undertaken to elicit surgeons' projections of the proportion of elective surgery that would be cancelled during the peak 12 weeks of disruption owing to COVID-19. These data were fed into a Bayesian β-regression model to estimate 12-week cancellation rates for elective surgery for 190 countries. Second, elective surgical case mix was determined for each Human Development Index (HDI) quintile using data from the Surgical Outcomes Studies and the expert response study. This case mix was applied to existing figures for overall country-level surgical volume to calculate expected specialty-specific surgical volumes for 190 countries. Finally, these surgical volume figures and the 12-week cancellation rate estimates were used to calculate total numbers of cancelled operations by specialty and country.

All 193 United Nations member countries were included in this study except Liechtenstein, North Korea and Somalia, as no surgical volume data were available for these three countries[12]. At present, the only region to have recovered from a large-scale SARS-CoV-2 outbreak is Hubei Province in China. Wuhan, the capital of Hubei, was in lockdown for 76 days (23 January 2020 to 8 April 2020). Therefore, the current best estimate for the duration of disruption to health systems caused by COVID-19 is around 12 weeks. This is consistent with advice that hospitals should plan to suspend non-urgent elective surgery for at least 12 weeks[4].

The secondary outcomes were total number of cancelled operations stratified by World Bank region (Europe and Central Asia, East Asia and Pacific, Latin America and the Caribbean, North America, Middle East and North Africa, South Asia, Sub-Saharan Africa), World Bank country income group (high, upper–middle, lower–middle, low), and surgical specialty. Specialty-specific cancellation totals were calculated for surgical specialties accounting for 5 per cent or more of the global surgical case mix (*Table S1*, supporting information). This included colorectal, head and neck, gynaecological, orthopaedic, obstetric, plastics,

Table 1 Best estimates of cancelled operations over a 12-week period of peak disruption, by specialty group

	Normal volume*	Estimated cancellations	12-week cancellation rate (%)
Cancer surgery			
Colorectal	1 353 952	486 563	35·9
Gynaecology	834 839	328 505	39·3
Head and neck	959 190	373 603	38·9
Plastics	505 294	178 362	35·3
Upper gastrointestinal and hepatobiliary	1 258 862	498 885	39·6
Urology	1 250 175	458 151	36·6
Benign surgery			
Colorectal	1 201 825	976 992	81·3
Gynaecology	2 665 361	2 175 774	81·6
Head and neck	4 845 604	3 950 551	81·5
Orthopaedics	7 677 515	6 295 041	82·0
Plastics	933 822	764 033	81·8
Upper gastrointestinal and hepatobiliary	2 728 786	2 223 194	81·5
Urology	3 051 523	2 492 604	81·7
Other	8 273 626	6 760 731	81·7
Obstetrics	1 735 483	441 611	25·4
Total	39 275 857	28 404 603	72·3

*Surgical volume at full capacity (no cancellations).

upper gastrointestinal (including hepatobiliary surgery) and urological surgery. Colorectal, head and neck, gynaecological, plastics, upper gastrointestinal and urological surgery were further stratified into operations performed for cancer *versus* benign pathology. Orthopaedic surgery was not stratified in this way as cancer accounts for a very small proportion of orthopaedic operations. Specialties that individually account for under 5 per cent of surgical case mix were pooled into an ‘other surgery’ category, including breast surgery, cardiac surgery, neurosurgery, thoracic surgery and vascular surgery. Therefore, a total of 15 specialty groups were included in this study (*Table 1*).

Twelve-week elective surgery cancellation rates

Senior surgeons were invited to participate in an expert response study to elicit their projections for the proportion of elective surgery that would be cancelled during the peak 12 weeks of disruption owing to COVID-19. Surgeons were contacted through the global CovidSurg network and asked to enter their estimates into an online database. The questionnaire was open from 20 to 30 March 2020.

Experts were asked to provide estimates for each of the 15 specialty groups included in this study. For each specialty group, experts provided their best estimate (the most likely 12-week cancellation rate), as well as a lower bound estimate (the lowest possible cancellation rate) and an upper bound estimate (the highest possible cancellation rate). If the SARS-CoV-2 outbreak had resolved at the experts’ hospital, they were asked to report actual rates of cancelled surgery due to the outbreak. If the outbreak was ongoing, experts were asked to project likely cancellation rates going forward. If the experts’ hospital had not yet experienced a SARS-CoV-2 outbreak, they were asked to estimate what would happen in the event of an outbreak.

After the expert response study questionnaire had closed, responses were matched by hospital and, where there was more than one expert participating per hospital, median values for each data point were calculated, so that there was one consolidated response per hospital. Overall median values for the best estimate and upper/lower bounds were then calculated for each participating country for cancer surgery, surgery for benign disease and obstetric (elective caesarean section) operations.

A Bayesian β-regression model was developed with 2018 HDI as a predictor, in order to establish 12-week cancellation rate estimates for all 190 countries included in the study (*Table S2*, supporting information). HDI is a composite index of life expectancy, education and per-capita income indicators, and its relationship with surgical outcomes has been validated previously[13,14].

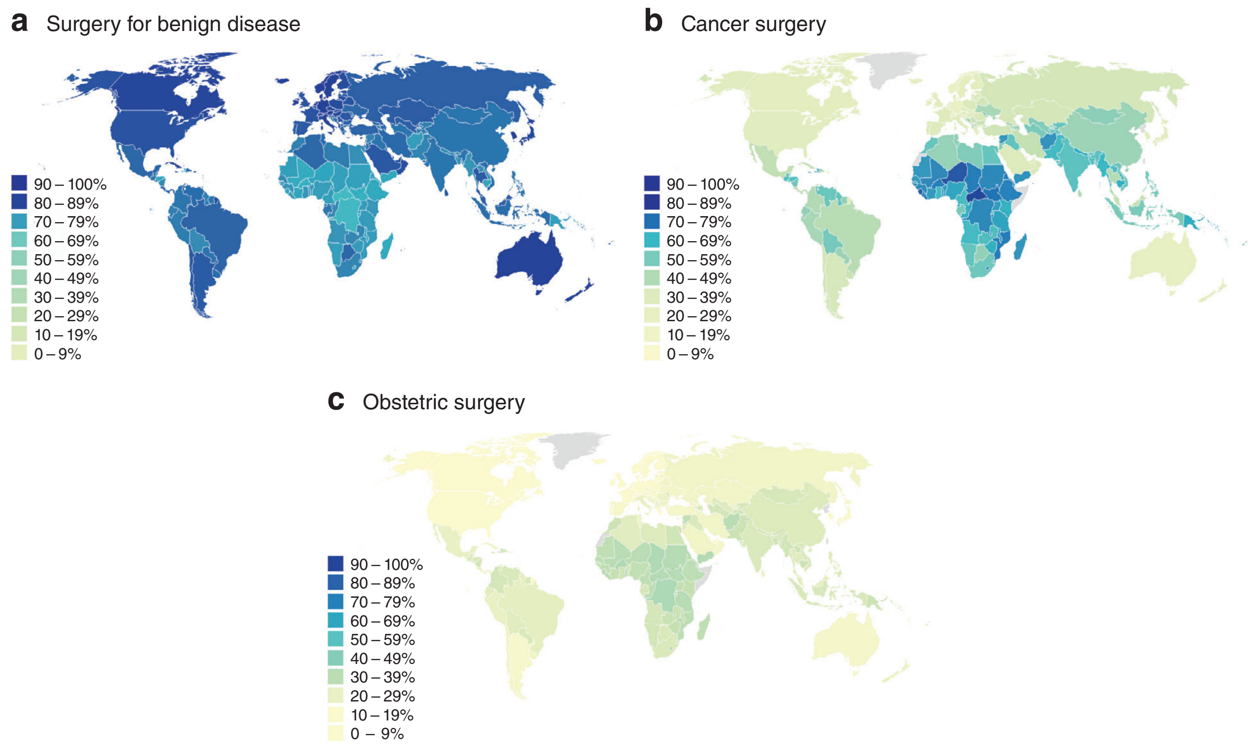
Non-informative priors were used with sensitivity analyses done on alternative priors and different chain initiation points or chain lengths. A restricted cubic spline transformation was applied to the continuous representation of the HDI rank (rank 1 being the most developed country and rank 190 the least developed) to account for potential non-linearity. This was substituted into the final β-regression model and posterior predictions were made for each HDI rank. The model was fitted for the best estimates and lower/upper bounds for cancer surgery, surgery for benign disease and obstetric (caesarean section) operations.

Surgical case mix

The best available global data on surgical case mix are from the African Surgical Outcomes Study, European Surgical Outcomes Study and International Surgical Outcomes Study[15–17]. These were prospective cohort studies that captured all adults undergoing surgery in participating facilities, providing case-mix data for a total of 102 539 patients across 64 countries. No comparable global case-mix data exist for paediatric surgery, so this study was limited to adults.

Raw data from the three Surgical Outcomes Studies were pooled to estimate case mix by HDI quintile (*Table S2*, supporting information). First, the case mix was determined

Fig. 2 **Country-level 12-week cancellation rates, by type of surgery**



a Surgery for benign disease, **b** cancer surgery and **c** obstetric surgery.

according to urgency: elective *versus* emergency. Next, within elective surgery the case mix was stratified by specialty. To determine cancer *versus* benign surgical case mix, the expert response study participants were asked to estimate the proportions of colorectal, head and neck, gynaecological, plastics, upper gastrointestinal and urological operations performed in their hospitals for cancer. Hospital-level results were then pooled by HDI quintile to calculate median proportions of cancer surgery for each specialty.

Surgical volume

A previous report[12] identified total country surgical volume for 72 countries (presented as point estimates) and modelled estimates for a further 120 countries (presented as confidence intervals). As only overall total (paediatric surgery) country volumes were available, population age-structure data from the World Bank were used to estimate total adult surgical volume for each country. Adults were defined as people age 15 years and above, consistent with age categories used for population data by the World Bank.

Country-level surgical volumes for each of the 15 specialty groups included in this study were calculated based on the country-specific adult surgical volume and case mix for the appropriate HDI quintile. For the best estimate of total cancellations, the point estimate (if provided) or the midpoint of the confidence interval for country-level surgical volume was used to calculate specialty-specific country-level surgical volume.

Totals for cancelled surgery

Country-level surgical volume data and modelled 12-week cancellation rates were used to calculate specialty group-specific totals for adult elective operations cancelled during the peak 12 weeks of disruption. The best estimate for the number of cancelled operations was based on the modelled best estimates for 12-week cancellation rates.

Surgical recovery

The time it would take countries to clear the backlog of operations resulting from 12 weeks of disruption owing

Table 2 Weekly totals for best estimates of cancelled operations, by country

Weekly total operations cancelled	Data by country
< 1000	Albania (567), Andorra (41), Antigua and Barbuda (54), Bahamas, The (280), Bahrain (514), Barbados (193), Belize (57), Benin (157), Bhutan (103), Botswana (792), Brunei Darussalam (249), Burkina Faso (237), Burundi (110), Cabo Verde (49), Cambodia (601), Cameroon (744), Central African Republic (32), Chad (29), Comoros (24), Congo, Democratic Republic (642), Congo, Republic (155), Cyprus (347), Djibouti (45), Dominica (27), Equatorial Guinea (211), Eritrea (78), Eswatini (195), Fiji (175), Gabon (242), The Gambia (30), Grenada (43), Guinea (141), Guinea-Bissau (35), Guyana (93), Haiti (305), Honduras (974), Iceland (297), Jamaica (964), Kiribati (7), Kyrgyz Republic (877), Lao People's Democratic Republic (192), Lesotho (115), Liberia (168), Luxembourg (564), Madagascar (231), Malawi (283), Maldives (237), Mali (347), Malta (554), Marshall Islands (16), Mauritania (116), Mauritius (260), Micronesia, Federated States (22), Monaco (32), Montenegro (268), Mozambique (370), Namibia (497), Nauru (7), Nepal (277), Niger (206), North Macedonia (711), Palau (15), Papua New Guinea (338), Rwanda (349), Samoa (13), San Marino (16), Sao Tome and Principe (18), Senegal (267), Seychelles (232), Sierra Leone (110), Solomon Islands (55), South Sudan (135), St Kitts and Nevis (33), St Lucia (76), St Vincent and the Grenadines (36), Suriname (243), Tajikistan (680), Tanzania (808), Timor-Leste (48), Togo (137), Tonga (26), Trinidad and Tobago (892), Tuvalu (4), Uganda (890), Vanuatu (15), Yemen, Republic (188), Zambia (418), Zimbabwe (810)
1000–9999	Afghanistan (1048), Angola (1612), Armenia (1124), Azerbaijan (1556), Bangladesh (2671), Bolivia (1094), Bosnia and Herzegovina (1625), Bulgaria (5109), Costa Rica (1734), Cote d'Ivoire (1153), Croatia (2086), Cuba (5578), Czech Republic (6531), Denmark (5622), Dominican Republic (3934), Ecuador (2012), Egypt, Arab Republic (9055), El Salvador (1200), Estonia (1255), Ethiopia (1124), Finland (6053), Georgia (1868), Ghana (1212), Greece (7492), Guatemala (1119), Iraq (3420), Ireland (1376), Israel (3766), Jordan (1839), Kazakhstan (7339), Kenya (1780), Kuwait (2593), Latvia (3565), Lebanon (2717), Libya (2060), Lithuania (2945), Moldova (1564), Mongolia (1283), Morocco (1302), Myanmar (1674), New Zealand (2721), Nicaragua (1351), Nigeria (9543), Norway (5370), Oman (1005), Pakistan (3746), Panama (2409), Paraguay (2211), Peru (7478), Portugal (8885), Qatar (1933), Romania (9135), Saudi Arabia (9410), Serbia (3476), Singapore (4418), Slovak Republic (4644), Slovenia (1524), Sri Lanka (3509), Sudan (3485), Switzerland (9162), Syrian Arab Republic (1697), Tunisia (3501), Turkmenistan (1208), United Arab Emirates (6402), Uruguay (2292), Uzbekistan (6988), Vietnam (7110)
10 000–49 999	Algeria (12 870), Argentina (27 088), Austria (11 967), Belarus (17 569), Belgium (22 660), Canada (32 881), Chile (11 696), Hungary (13 959), India (48 728), Indonesia (31 050), Iran, Islamic Republic (32 099), Korea, Republic (17 267), Malaysia (12 891), Mexico (15 315), Netherlands (15 847), Philippines (13 593), Poland (22 656), South Africa (12 795), Spain (45 449), Sweden (14 588), Thailand (18 332), Ukraine (21 943), UK (43 307), Venezuela, RB (17 234)
50 000–99 999	Australia (67 149), France (58 708), Germany (75 730), Italy (50 552), Russian Federation (93 688), Turkey (82 002)
≥ 100 000	Brazil (247 444), China (326 177), Colombia (113 082), Japan (113 324), USA (343 670)

Values in parentheses are weekly total of cancelled operations for each country.

to COVID-19 was estimated. It was assumed that cancelled obstetric (caesarean section) operations would not need to be rescheduled after the pandemic. Therefore, the time taken to clear country-level backlogs of operations for benign disease and cancer was based on country-level baseline volumes of surgery for these conditions. The number of whole or part weeks needed to clear these backlogs was calculated based on 10, 20 and 30 per cent increases in baseline surgical volume.

Sensitivity analyses

An estimate for the minimum number of operations likely to be cancelled was based on the lowest likely baseline surgical volume (the lower bounds for total surgical volume estimates where provided) and the modelled lower bounds for 12-week cancellation rates. An estimate for the maximum number of operations likely to be cancelled was based on the highest likely baseline surgical volume (the upper bounds for total surgical volume estimates where provided) and modelled upper bounds for 12-week cancellation rates.

Analyses were done using R version 3.6.3 and rstan (the R interface to the statistical inference language Stan) and the packages brms and finalfit (R Foundation for Statistical Computing, Vienna, Austria).

Results

Twelve-week cancellation rates

From a total of 538 submissions to the expert response study (*Fig. S1*, supporting information), data were available for 359 hospitals in 71 countries (*Table S3*, supporting information). Proportions of surgery projected to be cancelled were consistently estimated to be higher for benign conditions than for obstetrics (elective caesarean sections). Proportions of cancer surgery projected to be cancelled were lower in the most developed countries compared with the least developed ones (*Fig. S2*, supporting information).

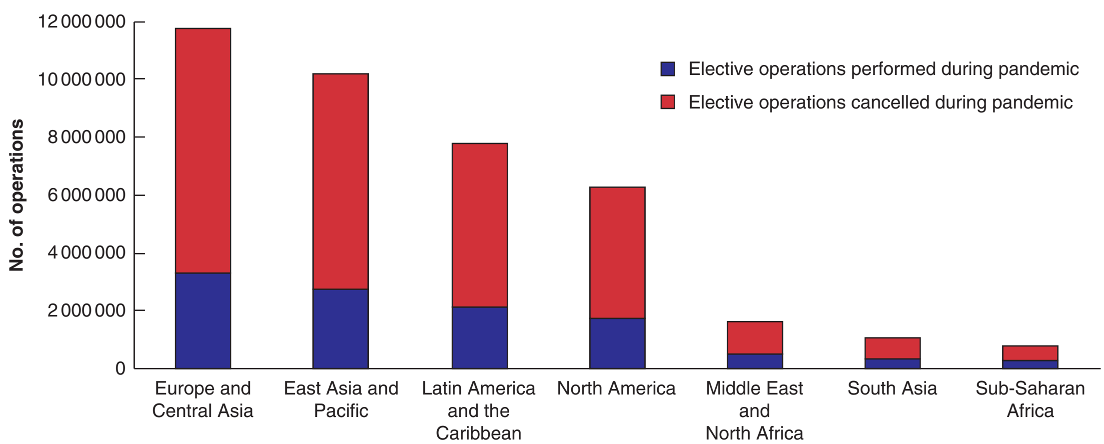
Based on the Bayesian β-regression model, best estimates for country-level 12-week cancellation rates for cancer surgery ranged from 23·4 to 77·1 per cent, whereas they

Table 3 Best estimates for cancelled operations over a 12-week period of peak disruption, by country income and region

	Surgery for benign disease	Cancer surgery	Obstetric surgery	Total
High income	11 803 371 (83·6)	937 740 (30·3)	89 073 (20·1)	12 830 185 (72·7)
East Asia and Pacific	2 276 604 (84·6)	167 830 (28·7)	17 271 (21·7)	2 461 704 (73·4)
Europe and Central Asia	4 895 041 (83·7)	384 630 (30)	39 106 (20·9)	5 318 777 (72·7)
Latin America and the Caribbean	188 143 (81·7)	22 331 (38·7)	3718 (23·4)	214 192 (70·5)
Middle East and North Africa	284 896 (83)	26 142 (33·9)	3076 (23·3)	314 114 (72·4)
North America	4 156 253 (83·1)	336 510 (31)	25 855 (17·5)	4 518 619 (72·4)
Sub-Saharan Africa	2434 (81)	297 (39·5)	47 (22·7)	2778 (70)
Upper–middle income	11 824 165 (80·4)	1 171 864 (43·4)	254 374 (26·4)	13 250 403 (72·1)
East Asia and Pacific	3 836 777 (79·6)	370 906 (47·8)	83 989 (27·9)	4 291 672 (72·8)
Europe and Central Asia	2 402 694 (81·5)	277 144 (37·8)	47 108 (23·2)	2 726 946 (70·2)
Latin America and the Caribbean	4 811 770 (80·6)	436 109 (43·6)	101 324 (26·9)	5 349 203 (72·8)
Middle East and North Africa	579 884 (80·4)	67 302 (44·5)	12 885 (24·9)	660 070 (71·4)
South Asia	38 931 (82·1)	5227 (45·1)	798 (24·6)	44 957 (72·2)
Sub-Saharan Africa	154 110 (77·7)	15 176 (55·6)	8270 (28·4)	177 555 (69·7)
Lower–middle income	1 906 718 (78·8)	200 315 (56·8)	86 875 (29·5)	2 193 909 (71·6)
East Asia and Pacific	591 840 (79·5)	63 188 (55·3)	16 827 (28·6)	671 855 (73·2)
Europe and Central Asia	338 114 (80·8)	31 754 (48·3)	6595 (24·4)	376 463 (73·7)
Latin America and the Caribbean	47 844 (76·7)	4839 (57·8)	2749 (28·8)	55 433 (69·1)
Middle East and North Africa	144 904 (77·7)	14 644 (56)	7282 (29·9)	166 830 (70·4)
South Asia	571 190 (79)	58 633 (60·1)	33 156 (28·9)	662 980 (70·9)
Sub-Saharan Africa	212 826 (75·1)	27 257 (67·8)	20 266 (33·7)	260 349 (67·8)
Low income	104 668 (75·1)	14 150 (70·2)	11 289 (34·6)	130 106 (67·7)
Europe and Central Asia	7055 (78·6)	689 (57·2)	418 (30·4)	8162 (70·7)
Latin America and the Caribbean	2900 (72·1)	405 (69·1)	355 (36·5)	3660 (65·6)
Middle East and North Africa	18 259 (77·3)	2415 (70·2)	1941 (34)	22 615 (69)
South Asia	12 872 (75·2)	1710 (69·8)	1311 (34·4)	15 892 (68)
Sub-Saharan Africa	63 582 (74·2)	8931 (71·6)	7264 (35·1)	79 777 (67·1)

Values in parentheses are cancellation rate during the 12 weeks of peak disruption owing to COVID-19. There are some small inconsistencies between totals due to differences in how figures have been rounded.

Fig. 3 Best estimates for number of elective operations cancelled during the peak 12 weeks of disruption due to COVID-19, by geographical region



Elective operations performed are those that are projected not to be cancelled during the 12 weeks of peak disruption owing to COVID-19.

Table 4 Projected total cancelled operations over a 12-week period of peak disruption, by specialty and region

	East Asia and Pacific	Europe and Central Asia	Latin America and the Caribbean	Middle East and North Africa	North America	South Asia	Sub-Saharan Africa	Total
Colorectal	370 947 (271 699–525 058)	429 080 (293 754–648 207)	289 478 (225 678–387 241)	66 360 (40 354–107 578)	216 938 (82 055–557 016)	51 498 (29 220–84 688)	39 253 (23 429–63 129)	1 463 554 (966 189–2 372 917)
Gynaecology	615 432 (465 320–845 332)	726 822 (527 138–1 048 555)	438 252 (351 688–568 490)	109 110 (70 281–168 401)	413 412 (174 874–996 313)	108 772 (61 384–179 841)	92 479 (54 885–149 462)	2 504 279 (1 705 570–3 956 394)
Head and neck	1 273 813 (992 658–1 697 114)	1 145 636 (846 679–1 619 047)	1 040 920 (852 507–1 320 423)	161 277 (102 965–252 346)	599 701 (257 022–1 433 471)	56 571 (33 227–90 353)	46 237 (27 997–73 646)	4 324 155 (3 113 055–6 486 400)
Obstetrics	118 086 (73 147–170 326)	93 227 (61 570–152 867)	108 147 (68 085–153 903)	25 184 (13 781–47 053)	25 855 (10 451–97 857)	35 266 (21 493–64 886)	35 846 (19 567–63 694)	441 611 (268 094–750 586)
Orthopaedics	1 552 527 (1 198 532–2 099 308)	2 026 572 (1 505 280–2 862 626)	1 040 757 (854 680–1 319 648)	244 121 (162 132–369 337)	1 196 372 (525 886–2 813 418)	144 637 (84 657–230 216)	90 054 (55 692–141 092)	6 295 040 (4 386 859–9 835 645)
Plastics	177 608 (127 932–257 002)	344 224 (247 596–499 065)	113 308 (85 578–157 432)	48 738 (30 970–76 291)	173 955 (71 275–427 356)	48 222 (27 550–78 677)	36 341 (21 834–58 177)	942 396 (612 735–1 554 000)
Upper gastrointestinal and hepatobiliary	782 347 (598 486–1 054 538)	747 601 (548 811–1 057 813)	668 231 (531 744–873 887)	113 529 (70 173–182 131)	335 765 (140 659–814 011)	46 355 (27 099–74 315)	28 253 (17 250–44 753)	2 722 081 (1 934 222–4 101 448)
Urology	758 344 (571 645–1 044 176)	889 675 (642 223–1 288 273)	561 714 (448 141–733 207)	120 947 (77 150–189 014)	484 983 (201 581–1 181 362)	73 061 (42 221–117 986)	62 031 (37 381–99 027)	2 950 755 (2 020 342–4 653 045)
Other surgery	1 776 126 (1 390 121–2 366 924)	2 027 511 (1 528 468–2 816 774)	1 361 682 (1 122 998–1 717 845)	274 363 (179 792–420 180)	1 071 638 (471 057–2 520 091)	159 448 (93 597–253 148)	89 964 (56 058–140 272)	6 760 732 (4 842 091–10 235 234)
Total	7 425 231 (5 689 539–10 059 779)	8 430 348 (6 201 518–11 993 227)	5 622 488 (4 541 098–7 232 076)	1 163 629 (747 598–1 812 332)	4 518 618 (1 934 859–10 840 895)	723 829 (420 448–1 174 112)	520 459 (314 092–833 252)	28 404 603 (19 849 153–43 945 672)

Values are best estimate (range). There are some small inconsistencies between totals due to differences in how figures have been rounded.

ranged from 71·2 to 87·4 per cent for surgery for benign conditions, and from 17·4 to 37·8 per cent for obstetrics (*Fig. 2*; *Table S4*, supporting information).

Surgical volume

The best estimate for cancellations was based on a global annual adult elective surgical volume of 170 195 382 operations (*Fig. S3*, supporting information). Details of surgical case mix are provided in *Tables S5–S8* and *Figs S4–S7* (supporting information).

Total cancellations

The best estimate was that 28 404 603 operations would be cancelled or postponed globally during the peak 12 weeks of the COVID-19 pandemic. Worldwide 2 367 050 operations would be cancelled per week, with 11 countries cancelling more than 50 000 operations per week (*Table 2*).

Most of the cancelled or postponed operations were estimated to be for benign disease (90·2 per cent, 25 638 922 of 28 404 603), followed by cancer (8·2 per cent, 2 324 070 of 28 404 603) and obstetrics (1·6 per cent, 441 611 of 28 404 603) (*Table 1*). The best estimate was that the global 12-week cancellation rates would be 72·3 per cent (28 404 603 of 39 275 857) overall, 81·7 per cent (25 638 922 of 31 378 062) for benign disease surgery, 37·7 per cent (2 324 070 of 6 162 311) for cancer surgery and 25·4 per cent (441 611 of 1 735 483) for obstetrics (*Table 3*).

Overall, 12-week cancellation rates by World Bank region would range from 68·3 to 73·0 per cent. The most cancellations were projected to take place in Europe and Central Asia (8 430 348 procedures) and the least in Sub-Saharan Africa (520 459) (*Fig. 3* and *Table 4*), reflecting the low baseline surgical volume there. Country-level totals stratified by specialty are presented in *Table S9* (supporting information).

Surgical recovery

Based on a 20 per cent increase in baseline surgical volume, it was estimated that it would take countries a median of 45 (range 43–48) weeks to clear the backlog of operations resulting from 12 weeks of disruption due to COVID-19 (*Table S10*, supporting information). If baseline surgical volume were increased by 10 per cent, it would take countries a median of 90 (86–95) weeks to clear the backlog, whereas with a 30 per cent increase in baseline surgical volume this would take a median of 30 (29–32) weeks.

Sensitivity analyses

The minimum estimate was that 19 849 153 operations would be cancelled worldwide during the 12 weeks of peak disruption due to COVID-19 (1 654 096 per week), representing a 61·1 per cent 12-week cancellation rate (19 849 153 of 32 488 250). The maximum estimate was that 43 945 672 operations would be cancelled during the peak 12 weeks (3 662 139 per week), representing a 12-week cancellation rate of 86·2 per cent (43 945 672 of 50 960 625).

Discussion

This study has demonstrated the major burden of cancelled elective surgery due to the COVID-19 pandemic. Although a similar proportion of surgery will be cancelled across different country income settings and geographical regions, the greatest number of cancellations will be in upper–middle-income countries. Cancer surgery will be prioritized in most settings, with most cancellations relating to surgery for benign conditions, most frequently orthopaedics.

The risks of exposing patients to perioperative SARS-CoV-2 infection by performing surgery during outbreaks are high, but must be weighed against the risks of protracted treatment delays. Given that many health systems already lack sufficient capacity to meet the need for surgery[18], the impact of cancellations will be cumulative, adding to existing waiting lists. Governments will need to fund substantial increases in baseline surgical volume to clear backlogs, but this is likely to be costly. For example, based on an average cost of £4000 per operation, it would cost over £2 billion to clear the UK's backlog.

There is a risk that delayed treatment of benign conditions as a result of pandemic-related cancellations will lead to deterioration in individual patients' conditions, increasing disability and reducing their ability to work. This will lead to lead to substantial societal costs, particularly in low–middle income countries (LMICs) where catastrophic expenditure relating to surgical disease can lead to impoverishment[19,20].

This study has several limitations. Although estimates were based on the best available global surgical data, several assumptions were required. As the COVID-19 pandemic is ongoing, it was necessary for the expert response study participants to project forward their estimates for 12-week cancellation rates. Participants in countries where the pandemic was in its earliest stages, such as in Sub-Saharan Africa, may have had to base their estimates on experience in previous emergencies, rather than the specific circumstances of COVID-19. The uncertainty around these estimates was captured by recording both lower and upper bounds, as well as best estimates for 12-week cancellation rates. Surgical case mix was based principally on snapshot cohort studies that collected data across 64 countries[15–17]. Given the barriers to participation in research, particularly in LMICs[21], it is unknown how representative these data are of the global case mix. Most countries do not publish surgical volume data, so this study relied on previous estimates of country-level surgical volume.

The eventual geographical extent and intensity of the pandemic is currently unknown, but it is likely that most countries will be affected[22–24]. The country-level figures can be used to produce estimates of cancellations per week, allowing policymakers to adjust estimates according to the predicted duration of local outbreaks. Prediction of the impact of COVID-19 on elective surgery in local communities can inform local planning and resource prioritization.

Postpandemic surgical recovery planning should anticipate the possibility of repeat waves of SARS-CoV-2 infection[25], leading to additional periods of cancellation of elective surgery. Therefore, strategies to safely maintain surgical volume during and immediately after SARS-CoV-2 outbreaks should be explored. For example, time-sensitive surgery, such as cancer resection, can be performed in designated non-COVID-19 units that do not treat patients with COVID-19. Although the optimal organization of such surgical units is unknown, it is likely that they should carefully select low-risk patients who are unlikely to require intensive care and can be operated safely in satellite units. Both patients and staff will require rigorous screening to reduce the risks of cross-infection. Surgical recovery plans should also consider that an immediate return to high-volume surgery may not be possible. For example, adaptations to operating theatres, such as installation of negative pressure flow systems, may need to be expedited to reduce the delay to resumption of normal activity.

Future research should be prioritized to identify strategies to mitigate the risk of operating in COVID-19 environments, so that cancellations are minimized. For example, although ongoing trials are testing treatments for COVID-19[26–28], large randomized trials are also needed to test therapies to prevent postoperative COVID-19 pulmonary complications.

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Supporting information

Additional supporting information can be found online in the Supporting Information section at the end of the article.