Impact of the COVID-19 Pandemic on Emergency Adult Surgical Patients and Surgical Services

An International Multi-center Cohort Study and Department Survey

Jasmine Winter Beatty, MRCS,[*†] *Jonathan M. Clarke, PhD,*[‡✉] *Viknesh Sounderajah, MRCS,*[*†§]
Amish Acharya, MRCS,[*†§] *Simon Rabinowicz, MBBS,*[*] *Guy Martin, PhD,*[*†] *Leigh R. Warren, MBBS,*[*§]
Seema Yalamanchili, MRCS,[*†§] *Alasdair J. Scott, PhD,*[*†§] *Elizabeth Burgnon, MSc,*[*]
Sanjay Purkayastha, MD,[*†] *Sheraz Markar, PhD,*[*†] *and James M. Kinross, PhD*[*†], *on behalf of the*
PANSURG-PREDICT Collaborative[*]

Objectives: The PREDICT study aimed to determine how the COVID-19 pandemic affected surgical services and surgical patients and to identify predictors of outcomes in this cohort.

Background: High mortality rates were reported for surgical patients with COVID-19 in the early stages of the pandemic. However, the indirect impact of the pandemic on this cohort is not understood, and risk predictors are yet to be identified.

Methods: PREDICT is an international longitudinal cohort study comprising surgical patients presenting to hospital between March and August 2020, conducted alongside a survey of staff redeployment and departmental restructuring. A subgroup analysis of 3176 adult emergency patients, recruited by 55 teams across 18 countries is presented.

Results: Among adult emergency surgical patients, all-cause in-hospital mortality (IHM) was 3.6%, compared to 15.5% for those with COVID-19. However, only 14.1% received a COVID-19 test on admission in March, increasing to 76.5% by July.

Higher Clinical Frailty Scale scores (CFS >7 aOR 18 87), ASA grade above 2 (aOR 4.29), and COVID-19 infection (aOR 5.12) were independently associated with significantly increased IHM.

The peak months of the first wave were independently associated with significantly higher IHM (March aOR 4.34; April aOR 4.25; May aOR 3.97), compared to non-peak months.

During the study, UK operating theatre capacity decreased by a mean of 63.6% with a concomitant 27.3% reduction in surgical staffing.

Conclusion: The first wave of the COVID-19 pandemic significantly impacted surgical patients, both directly through co-morbid infection and indirectly as shown by increasing mortality in peak months, irrespective of COVID-19 status.

Higher CFS scores and ASA grades strongly predict outcomes in surgical patients and are an important risk assessment tool during the pandemic.

Keywords: acute surgery, acute surgical presentation, adult, adult surgical patients, analytical survey, CCU, Charlson Comorbidity Index, Chest radiograph, clinical frailty, Clinical Frailty Scale, comorbidity, computed tomography, coronavirus, COVID-19, COVID-19 prevalence, COVID-19 surge, COVID-19 test, COVID-19 test on admission, critical care, critical care bed, critical care capacity, emergency general surgery, emergency surgery, frailty, HDU, high dependency care, high dependency care bed, humans, ICU, in-hospital mortality, intensive care, intensive care bed, intensive care capacity, intensive therapy, international, ITU, length of stay, longitudinal, medical management, mortality, multi-center, multicentre, multinational, multi-national, nasopharyngeal swab, observational cohort study, operating room, operating theatre, operating theatre repurposing, pandemic, patient risk assessment, peak of pandemic, perioperative, pre-operative, pre-operative COVID-19 test, pre-operative risk assessment, prospective, redeployment, retrospective, risk assessment, RT-PCR test, SARS-CoV-2, SARS-CoV-2 test, surge period, surgery, surgical intervention, surgical procedure, surgical service disruption, surgical service restructuring, surgical staff, surgical staff redeployment, survey

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The COVID-19 pandemic has led to significant disruption in the provision of surgical services, with an estimated cancellation of 28 million elective operations worldwide during the first wave alone,[1] in addition to the suspension of diagnostic and interventional pathways.[2,3] Early data suggested an overall 30-day postoperative mortality of 23.8% for surgical patients who contracted COVID-19.[4] However, surgical care provision during the pandemic has been subject to local variations in biosecurity strategies, COVID-19 incidence rates, critical care and operating theatre capacity and staffing availability.[3,5] Many surgical centers also shifted towards conservative or ambulatory treatment pathways to avoid inpatient admission and potential nosocomial transmission.[6] The exact extent of these changes has not being accurately reported, and there is a requirement to understand the longitudinal impact of service reorganization and resource depletion upon the outcomes of surgical patients during the pandemic, irrespective of their COVID-19 status.

From the *Department of Surgery & Cancer, Imperial College London, London, United Kingdom; †Imperial College Healthcare NHS Trust, London, United Kingdom; ‡Centre for Mathematics of Precision Healthcare, Imperial College London, United Kingdom; and §Institute of Global Health Innovation, Imperial College London, London, United Kingdom.

✉j.clarke@imperial.ac.uk.

[*] Collaborators are listed in Supplementary File 1, http://links.lww.com/SLA/D377.

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The aim of this multi-center international study was therefore to characterize surgical outcomes during the initial wave of the COVID-19 pandemic and to identify prognostic features that could be used to more accurately stratify patient risk for future surges.

METHODS

Study Design

The PREDICT study is composed of an analytical service survey and a multi-center international observational cohort study, conducted by 55 teams across 18 countries. The service survey was developed and reported according to recognized international guidelines.[7] The patient cohort study has been conducted and reported in accordance with the STROBE guidelines for observational studies. The study protocol is available from https://www.pansurg.org/predict.

Only routinely collected and pseudo-anonymised data was captured throughout the course of the study period. Ethical approval was obtained from the National Health Service (NHS) Health Research Authority (Ref - 20/HRA/1851). At all sites, local principal investigators were responsible for obtaining appropriate local approval. Individual patient consent was not required on account of the study design and the ongoing public health emergency. Issues related to study and data management were managed by a dedicated PREDICT management committee.

Participants

All emergency patients who presented to participating secondary and tertiary centres with an acute surgical pathology related to general surgery, endocrine surgery, vascular surgery, cardiothoracic surgery, and trauma and orthopaedic surgery during the first wave of the pandemic were eligible to be included in this analysis. Inclusion was irrespective of admission to hospital or COVID-19 status. Entries comprising either missing or inconsistent data after the validation process were excluded before data analysis.

At each study site, the direct clinical team were responsible for identifying patients who fulfilled inclusion criteria. The manner in which these patients were identified varied between hospitals. Both retrospective and prospective data capture was encouraged to identify all eligible patients within the study period. Sampling methods were not employed. Participants were recruited starting from the March 11, 2020, the day upon which the pandemic was formally declared by the World Health Organization,[8] up until the August 30, 2020, before the beginning of the second wave. Interim analyses were not performed during this period.

Data Collection

Hospitals were recruited through social media and web-based campaigns. When requested, site initiation visits were conducted virtually (Zoom Video Communications, United States of America).

Study data was collected and managed using the Research Electronic Data Capture (REDCap, United States of America) online tool hosted at Imperial College London, United Kingdom (UK). REDCap is a GDPR compliant, secure data environment that has been validated for the use of large-scale data capture for multi-center research studies.[9]

An analytical service survey was developed by members of the PREDICT group, including questions related to hospital structures and surgical team composition (Supplementary File 2, http://links.lww.com/SLA/D377). Baseline data was collected upon registration and weekly thereafter to determine how services were restructured in response to the pandemic.

Before creating the case report form, the PREDICT management committee undertook a review of peer-reviewed and grey literature to identify pertinent data capture fields and to incorporate validated clinical scoring systems. The chosen fields were corroborated against notable multi-center patient outcome audits such as the UK's National Emergency Laparotomy Audit or the Trauma Audit Research Network, to assure completeness.

Comprehensive and longitudinal patient data was collected (Supplementary File 3, http://links.lww.com/SLA/D377). Baseline demographics including age, medical comorbidities, Charlson Comorbidity Index (CCI)[10] and the Clinical Frailty Scale (CFS),[11] in addition to clinical presentation, diagnoses, investigations and management decisions, were collected.

In the event of admission to hospital, longitudinal information was captured to characterize each inpatient course (Supplementary File 3, http://links.lww.com/SLA/D377). This included data regarding surgical intervention, complications, critical care admission, ASA grade (American Society of Anesthesiologists physical status classification system), ongoing COVID-19 status, and patient outcome. Before locking the dataset for statistical analysis, local principal investigators were asked to validate the completeness and accuracy of data entry.

Outcomes

The study outcomes have been aligned with Donabedian's three component model to evaluate quality of medical care: structure, process, and outcome.[12] Through this validated framework, we are able to characterize and evaluate the manner in which surgical pathways adapted to the evolving pandemic.

The composite primary outcome was the dynamic impact of the first COVID-19 wave upon structures, processes and outcomes associated with surgical treatment pathways. Structures related to models of care including operating theatre and critical care capacity, and surgical team composition. Processes related to use of COVID-19 diagnostic methods, including both modality and frequency of testing. Outcomes related to mortality rates and length of hospital stay. Secondary outcome measures were evaluated through a multivariate analysis to determine which patient, physiological, and admission-related factors were associated with less favorable outcomes.

As the study aims to present a longitudinal assessment of surgical practice during the COVID-19 pandemic, four time-points were selected to facilitate comparison. These time-points are set to correspond with the publication of pivotal practice-changing guidance or critical information affecting surgical practice during the pandemic:

A. Royal Colleges of Surgeons Guidance for surgeons working during COVID-19 pandemic - issued March 20, 2020[13];
B. Royal Colleges of Surgeons Guidance for surgeons updated with ASGBI, ACPGBI and AUGIS - issued April 5, 2020[14];
C. COVIDSurg collaboration study - published in the Lancet, May 20, 2020;[4]
D. D: Royal College of Surgeons Clinical guide to surgical prioritization – issued June 26, 2020.[15]

Statistical Analysis

Continuous variables were expressed as medians and interquartile ranges (IQR). Categorical variables were summarized as counts and percentages. Missing data were not Imputed. A power calculation was not undertaken given the absence of any meaningful relevant data when designing the study. Statistical significance was indicated by a P-value <0 05.

In-hospital mortality was examined using a multivariable binary logistic model including a panel of patient, admission and temporal features. Coefficients are reported as adjusted odds ratios (aOR). Length of hospital stay is modelled using a multivariable negative binomial regression model using the same panel of covariates as for in-hospital mortality. Coefficients are reported as incidence rate ratios (IRR).

Role of the Funding Source

The funders of the study did not have a role in the study design, data collection, analysis, and interpretation, or the writing of this report. The corresponding author and the analysis group had access to the whole dataset included in this study. The corresponding author and the writing committee had full responsibility for the decision to submit for publication.

RESULTS

A total of 3176 emergency patient episodes were entered for the period between March 9, 2020 and August 30, 2020. Data was collected from a total of 55 centers, from 18 countries. A list of departments that contributed data towards this analysis is presented in Supplementary File 4, http://links.lww.com/SLA/D377.

Of the total cohort, 1624 (51.1%) were male, and median age was 56 years (IQR = 38–74 years). 1866 patients (58.8%) were admitted under the care of general surgery teams, with a total of 13 surgical specialties represented. Among these, 1340 patients (42.3%) underwent surgical intervention. Demographics are presented in Table 1, patient numbers by consulting surgical specialty in Table 2.

Given the significant heterogeneity across healthcare systems of participating centers, and the predominance of UK responses, analysis of resource and staff restructuring were restricted to UK centers only. Of the 47 UK-based teams, 35 baseline registration surveys were included in the analysis after removing incomplete and duplicate entries.

Structures

Critical care (high dependency or intensive care) capacity was shown to increase by a mean of 96.3% (range -50 to -418.8%) from pre-COVID-19 levels amongst responding UK centers (Fig. 1). Only 1 team reported a reduction in critical care capacity during the pandemic. Conversely, the numbers of available operating theatres almost uniformly decreased amongst the same cohort (-63.6% decrease, range -100% to 0%). With respect to staffing, 30 out of 32 departments (93.8%) reported a reduction in overall surgical team staffing numbers (-27.2% reduction, range -60% to 10%), corresponding to redeployment of junior surgical staff to acute medical specialties (Fig. 1). Accordingly, surgical teams during the COVID-19 pandemic were predominantly composed of more senior staff, such as consultant/attending surgeons or surgical registrars/residents (Fig. 1).

TABLE 1. Description of the Patient and Clinical Features of the Dataset

		N	%
Total cases		3176	100.00
		Median	IQR
Age (yr)		56	(38 - 74)
Length of stay (d)		3	(1 - 9)
		N	%
Sex	Female	1528	48.11
	Male	1624	51.13
	Other	3	0.09
	Not recorded	21	0.66
Ethnicity	Asian	152	4.79
	Black	240	7.56
	Mixed	45	1.42
	Other	299	9.41
	White	1976	62.22
	Not recorded	464	14.61
Charlson Comorbidity Index	0	2017	63.51
	1–2	765	24.09
	≥3	394	12.41
Clinical Frailty Scale	≤2	1462	46.03
	3–4	824	25.94
	5–6	323	10.17
	≥7	103	3.24
Outcome	Not recorded	464	14.61
	Discharged	2812	88.54
	In hospital mortality	104	3.27
	Still in Hospital	65	2.05
	Not recorded	195	6.14

TABLE 2. Adult Emergency Patients According to Consulting Surgical Specialty

Referral or Admission Specialty	No. of patients	No. of operated patients
Bariatric surgery	16	6 (37.5%)
Colorectal surgery	106	49 (46.23%)
Emergency surgery	1125	484 (43.02%)
Endocrine Surgery	8	8 (100%)
General surgery	741	215 (29.01%)
Hepatopancreaticobiliary surgery	119	15 (12.6%)
Oesophago-gastric surgery	36	17 (47.22%)
Other	68	36 (52.94%)
Thoracic Surgery	5	4 (80%)
Trauma & Orthopaedics	618	340 (55.02%)
Trauma Surgery	102	55 (53.92%)
Urology	25	6 (24%)
Vascular surgery	202	105 (51.98%)

Processes

Within this cohort of 3176 patients, 138 (4.3%) patients had a concomitant diagnosis of COVID-19 infection. Of these, 17 (12.3%) were known to be COVID-19 positive on arrival to hospital, 73 (52.9%) tested positive on presentation, 20 (14.5%) patients tested positive pre-operatively, and a further 28 (20.3%) were found to be positive before discharge.

Most COVID-19 testing took place on presentation to hospital, with 1991 patients (62.7%) being tested on arrival, of which 73 were positive (3.7%). Longitudinal trends in both the frequency and modality of testing on arrival are represented in Fig. 2. The percentage of emergency surgical patients undergoing diagnostic investigation for COVID-19 infection significantly increased throughout the duration of the study, with 14 1% of patients being tested on arrival at time-point A compared to 76.5% at time-point D (two-tailed χ^2=62.9, P <0.0001). Nasopharyngeal swabs were the primary testing modality utilized on arrival throughout the study period, consisting a part of, or the entire diagnostic strategy in 1914 of tested patients (96.1%). Before time-point C, variation in testing modalities was observed, with nasopharyngeal swabs alone accounting for 55.9% of tested patients. At this time-point, in 34.4% of cases nasopharyngeal swabs were used in combination with either a plain chest radiograph (19.9%), computed tomography (CT, 11.7%) or both (2.8%), although in 9.7% of patients, radiological imaging alone was used. From time-point D onwards, nasopharyngeal swab alone accounted for 95.8% of all COVID-19 diagnostic tests performed, and the use of radiological modalities, even as an adjunct, was limited to only 42% of cases.

Outcomes

1342 cases (42.3%) identified during the study underwent operative management. This proportion did not significantly change

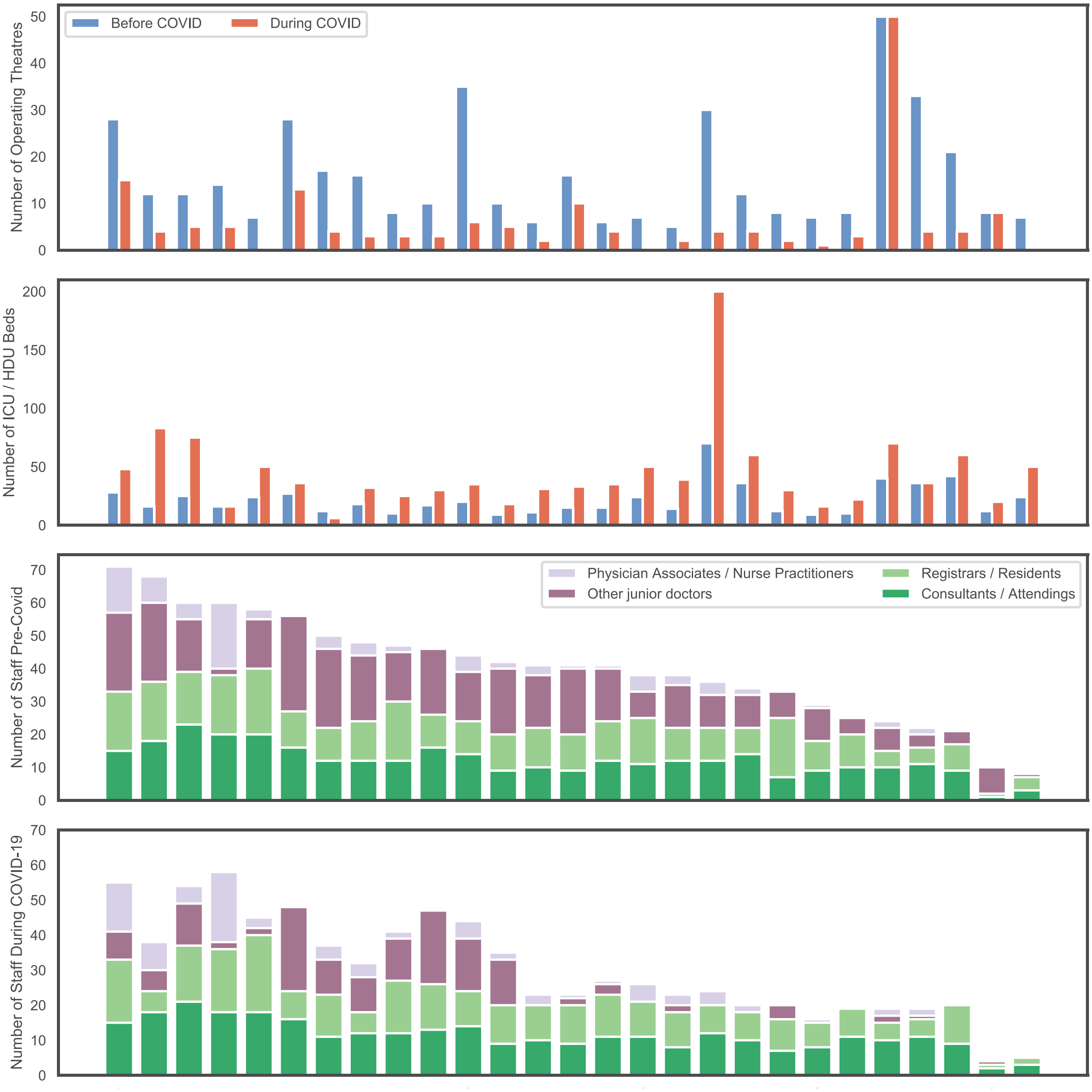

FIGURE 1. Details of findings related to Structures. From above down: 1) Operating theatre numbers before and during the pandemic as reported by surgical teams in the UK; 2) Intensive care bed numbers before and during the pandemic as reported by surgical teams in the UK; 3) and 4) Total numbers and proportion of surgical staff by grade before and during the pandemic as reported by surgical teams in the UK.

throughout the study, with no difference noted between time-points A (39.3%) and D (45.1%) (two-tailed χ^2=0.37, $P = 0.54$), as seen in Fig. 2. Similarly, the proportion of patients for whom surgical management was the intended treatment at presentation, did not significantly change over the study period (time-point A=40.9% vs time-point D=41.9%, χ^2=0.02, $P = 0.888$). Of patients with completed clinical episodes, all-cause in-hospital mortality was 3.6% (104/2916). In-hospital mortality (IHM) occurred for 4.2% of patients managed operatively compared to 3.1% of those managed non-operatively (two-tailed χ^2=2.26, $P = 0.13$).

Amongst 129 patients with a known COVID-19 diagnosis and completed clinical episodes, irrespective of management intent, the unadjusted all-cause in-hospital mortality rate was found to be 15.5%, with a median length of stay of 8 days (IQR=3–17 days). IHM for COVID-19 positive patients undergoing surgery was high at 18.9%, although this was not statistically significantly different from those whom did not undergo surgical intervention (18.9% vs 13.2% - two-tailed Fisher exact test, $P = 0.46$). However, patients who underwent surgery and had a positive COVID-19 test during the same admission episode had a higher risk of IHM than patients

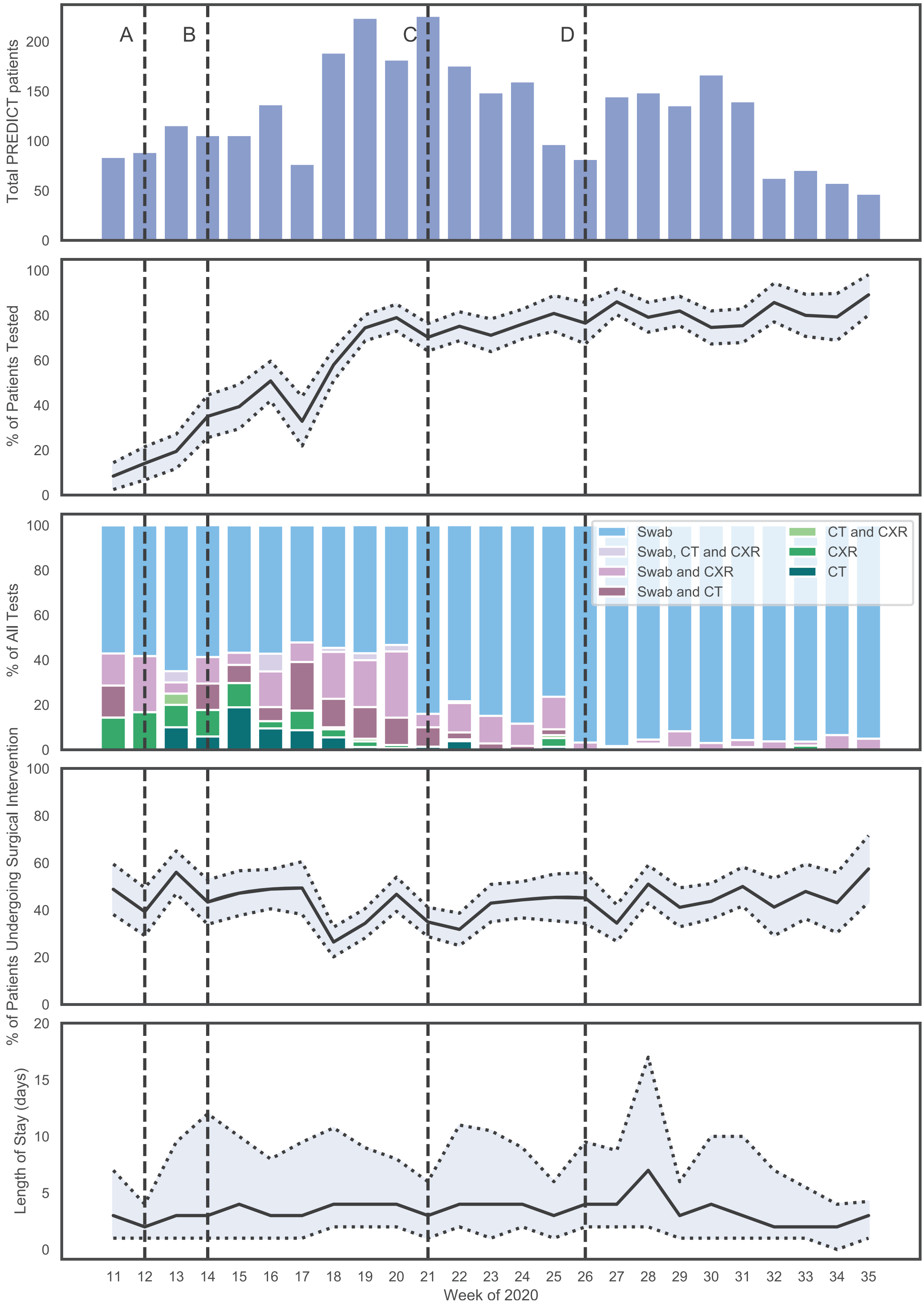

FIGURE 2. Details of findings related to Processes and Outcomes. From above down: 1) Weekly number of emergency adult surgical patient entered into the study (Interval represents 95% confidence intervals of proportions); 2) and 3) Longitudinal trends

TABLE 3. Logistic Regression Output for In-hospital Mortality. Coefficients are Reported as Odds Ratios

		Coefficient	***P* value**	**95% CI**	
Age		1.026	0.043	1.001	1.051
Sex	Female	Reference			
	Male	1.404	0.328	0.711	2.773
New Cancer Diagnosis	No	Reference			
	Yes	0.674	0.513	0.206	2.198
ICU Admission	No	Reference			
	Yes, planned	2.268	0.100	0.855	6.013
	Yes, unplanned	34.101	0.000	12.036	96.616
Charlson Comorbidity Index	0	Reference			
	1–2	0.512	0.176	0.194	1.352
	3+	1.894	0.177	0.749	4.786
Clinical Frailty Scale	1–2	Reference			
	3–4	2.058	0.233	0.629	6.734
	5–6	7.215	0.003	1.945	26.766
	7+	18.870	0.000	4.451	79.992
Pulse rate	Normal (≥51 & ≤90 bpm)	Reference			
	Abnormal	1.758	0.104	0.890	3.473
Oxygen saturations	Normal (≥96%)	Reference			
	Abnormal	1.732	0.115	0.875	3.428
Glasgow Coma Scale	Normal (15/15)	Reference			
	Abnormal	2.007	0.208	0.679	5.935
Systolic Blood Pressure	Normal (≥111 & ≤219 mmHg)	Reference			
	Abnormal	0.856	0.692	0.396	1.848
Temperature	Normal (≥36.1 & ≤38.0°C)	Reference			
	Abnormal	0.984	0.967	0.466	2.078
White blood cell count	Normal (> 4.5 & ≤11 x10^3 / μl)	Reference			
	Abnormal	1.166	0.664	0.582	2.335
Surgical intervention	No	Reference			
	Yes	1.326	0.471	0.616	2.853
Covid-19 +ve during admission	No	Reference			
	Yes	5.125	0.000	2.065	12.720
ASA grade	1 or 2	Reference			
	3 or more	4.292	0.009	1.446	12.742
Month	March	4.341	0.043	1.046	18.008
	April	4.253	0.029	1.161	15.582
	May	3.971	0.019	1.249	12.619
	June	1.878	0.340	0.515	6.854
	July	Reference			
	August	3.097	0.118	0.751	12.771
Intercept		0.000	0.000	0.000	0.001

receiving surgery without COVID-19 (18.9% vs 3.6%; two-tailed χ^2=25.93, $P < 0.0001$), although numbers in this analysis are very small.

The output from the logistic regression model for all-cause in-hospital mortality is shown in Table 3. COVID-19 infection was associated with a significant increase in mortality for all patients (aOR 5.12, CI 2.06–12.72). Amongst patient-related factors, age (aOR 1.06, CI 0.71–1.05), ASA category above 2 (aOR 4.92, CI 1.45–12.74), and higher Clinical Frailty Scale (mild-moderate (CFS 5–6) aOR 7.21, CI 1.94–26.77; severe (CFS >7) aOR 18.87, CI 4.45- 79.99), were associated with increased IHM. In addition, unplanned ICU admission (aOR 34.10, CI 12.04–96.62) was associated with a significant increase in IHM, while surgical intervention was not. After accounting for other patient factors, compared to July 2020, the first peak of the pandemic during March, April and May was associated with significantly higher in-hospital mortality for all patients irrespective of COVID-19 status (March aOR 4.34, CI 1.05–18.01; April aOR 4.25, CI 1.16–15.58; May aOR 3.97, CI 1.25–12.62).

With respect to length of hospital stay (LOS), a negative binomial regression model was undertaken for those patients with a known discharge from hospital, with outputs including coefficients, reported as IRR, in Table 4. Patient factors including increasing age (IRR 1.009, $P < 0.0001$), higher Charlson Comorbidity Index (compared to CCI = 0: CCI 1–2 IRR 1.21, p=0.018; CCI>3 IRR 1.43, P =0.002) and new cancer diagnosis (IRR 1.58, P = 0.001)

in the proportion of patients tested for COVID-19 and modality of testing; 4) Operative intervention as a proportion of all patients per week (Intervals represent 95% confidence intervals of proportions); 5) Weekly median Length of stay (shown as weekly medians with intervals representing upper and lower quartiles). Week 11 commenced on the March 9, 2020. Labels A-D correspond to A: Royal Colleges of Surgeons Guidance for surgeons working during COVID-19 pandemic - issued March 20, 2020, B: Royal Colleges of Surgeons Guidance for surgeons updated with ASGBI, ACPGBI and AUGIS - issued April 5, 2020' C: COVID Surg collaboration study - published in the Lancet, May 20, 2020, D: Royal College of Surgeons Clinical guide to surgical prioritization – issued June 26, 2020.

TABLE 4. Negative Binomial Regression Output for Length of Hospital Stay. Coefficients are Reported as Incidence Rate Ratios

		Coefficient	*P* value	95% CI	
Age		1.009	0.000	1.005	1.012
Sex	Female	Reference			
	Male	0.911	0.135	0.805	1.030
New Cancer Diagnosis	No	Reference			
	Yes	1.576	0.001	1.191	2.086
ICU Admission	No	Reference			
	Yes, planned	2.269	0.000	1.736	2.966
	Yes, unplanned	2.148	0.004	1.285	3.589
Charlson Comorbidity Index	0	Reference			
	1–2	1.207	0.018	1.033	1.410
	3+	1.433	0.002	1.141	1.800
Clinical Frailty Scale	1–2	Reference			
	3–4	1.232	0.009	1.053	1.441
	5–6	1.090	0.511	0.843	1.410
	7+	0.905	0.627	0.603	1.356
Pulse rate	Normal ($\geq$51 & $\leq$90 bpm)	Reference			
	Abnormal	1.104	0.134	0.970	1.256
Oxygen saturations	Normal ($\geq$96%)	Reference			
	Abnormal	1.163	0.081	0.981	1.378
Glasgow Coma Scale	Normal (15/15)	Reference			
	Abnormal	1.885	0.002	1.271	2.795
Systolic Blood Pressure	Normal ($\geq$111 & $\leq$219 mmHg)	Reference			
	Abnormal	1.102	0.223	0.943	1.287
Temperature	Normal ($\geq$36.1 & $\leq$38.0°C)	Reference			
	Abnormal	0.772	0.000	0.675	0.883
White blood cell count	Normal (>4.5 & $\leq$11 x10^3 / μl)	Reference			
	Abnormal	1.016	0.804	0.898	1.150
Surgical intervention	No	Reference			
	Yes	1.419	0.000	1.248	1.615
Covid-19 +ve during admission	No	Reference			
	Yes	1.339	0.060	0.988	1.815
ASA grade	1 or 2	Reference			
	3 or more	1.058	0.453	0.914	1.224
Month	March	0.820	0.115	0.641	1.049
	April	0.619	0.000	0.489	0.783
	May	0.782	0.006	0.657	0.930
	June	0.851	0.091	0.706	1.026
	July	Reference			
	August	0.532	0.000	0.426	0.664
Intercept		4.329	0.000	3.314	5.654

CI indicates confidence interval.

were significantly associated with a longer length of hospital stay. Compared to those with lowest Clinical Frailty Scores (1–2), those with CFS of 3 or 4 were associated with increased LOS (IRR 1.23, *P* =0 009), whereas mild-moderate (5–6) and severe scores (> 7) were not. Abnormal GCS (<15) was associated with a longer LOS (IRR 1.88, *P* =0.002), whereas abnormal temperature on presentation was associated with shorter LOS (IRR 0.77, *P* <0.0001). Admission-related factors, including ICU stay (planned IRR 2.27, p=0.001; unplanned IRR 2.15 *P* =0.004) and operative management (IRR 1.42, *P* <0.0001) were associated with increased LOS. Compared to July 2020, LOS was significantly shorter in April (IRR 0.62, *P* <0.0001), May (IRR 0.78, *P* =0.006) and August (IRR 0.53, *P* <0.0001).

DISCUSSION

To our knowledge, this is the largest and longest international longitudinal COVID-19 study, conducted over a six-month time period during the first wave of the pandemic which assesses the changes in structures, processes and outcomes of surgical patients. It has demonstrated that as critical care capacity was scaled up to meet the demands of COVID-19 patients, operating room capacity decreased by an average of 63.6%, with an associated decline in surgical staffing of 27.2%, and a corresponding shift towards the delivery of care by more senior clinicians. Previous international surveys as well as small cohort studies have shown that early on in the pandemic the numbers of patients attending the emergency room or requiring surgical consultations significantly dropped.[16–19] In this analysis we have shown how in keeping with reports provided by international surgical bodies,[13,15] emergency surgical activity remained constant throughout the first wave. This phenomenon, also reported in other surgical cohorts,[20] seems to be irrespective of the geographical differences in COVID-19 prevalence. As such, the redeployment of senior members of surgical teams into non-familiar roles such as critical care areas should be carefully considered as this may significantly dilute a surgical service's ability to deliver timely management and treatment. The data presented here suggests that it is imperative that the planning of both acute and elective surgical services remains an essential component of current COVID-19 waves as well as of future pandemic planning strategies.

During the early phase of the pandemic there was significant heterogeneity in the diagnostic criteria for COVID-19 applied to surgical cohorts (Fig. 2). Testing modality was not a specific recommendation of the initial surgical guidance within the UK issued in May 2020,[21] although data suggested Chest CT as an important adjunct to detect COVID-19 infection in symptomatic patients with negative RT-PCR pre-operatively.[22] Health systems adapted to incorporate RT-PCR testing methods for SARS-CoV-2, with respiratory swabs becoming the primary diagnostic modality within 11 weeks of the pandemic being declared, and accounting for almost 96% of tests at 16 weeks. CT was likely abandoned as COVID-19 cases declined and the superior diagnostic accuracy of RT-PCR was proven.[23] The implications of the low testing rates demonstrated here are significant for this analysis and others; the reported incidence of COVID-19 in previous surgical studies has varied considerably, ranging from 4% to 26.1%.[4,20] As these were largely based on early COVID-19 pandemic admissions, it is likely that this data is inaccurate. In turn this suggests that previously defined surgical co-morbidity of surgical patients with COVID-19 is likely to be under reported. Diagnostic strategies for COVID-19 have subsequently evolved, as have elective biosecurity screening strategies and surgical pathway design.[24] Modern guidance on perioperative care has now placed significant emphasis on preadmission testing and re-testing during surgical admissions. These should be stringently followed to prevent future mortality in surgical cohorts.

The unadjusted all-cause mortality of patients undergoing surgery in this cohort was comparable to those treated conservatively (4.2% v. 3.1%). As with previous studies, we found that the overall mortality, irrespective of management, was more than 4 times higher in those diagnosed with COVID-19 infection. Of note, the absolute COVID-19 mortality rate of 15.5% in emergency surgery is lower than reported in comparable studies,[4] and a meta-analysis,[25] although it has been reported to range from 11 to 77% in smaller cohorts.[19,20,26–28] Whilst the findings reported here may be due to the fact that only 4.3% of patients tested positive, they may also be indicative of the longitudinal nature of this data collection. Previous analyses have suggested that the general rise in surgical mortality during COVID-19 surges may be due to the greater severity of presenting surgical pathologies, caused by delayed presentation to hospital.[28] Moreover, it is also possible that changes to surgical capacity and staff redeployment contributed to the worse surgical outcomes identified during the peak surge. Neither of these factors can be causally associated with surgical mortality based on this analysis, however both may have contributed to a multifactorial etiology.

In this cohort, only 56.6% of COVID-19 diagnosis were made pre-operatively; of the COVID-19 positive patients who underwent surgical intervention and died, COVID-19 status was known at the time of surgery in only two of the ten patients, suggesting the remaining eight were either undiagnosed or acquired the infection post-operatively. The implications of the low admission and pre-operative testing rates demonstrated here are significant for this analysis and others; the reported incidence of COVID-19 in previous surgical studies has varied from 4% to 26.1%.[4,20] As these retrospective studies have largely been based on admissions early on in the pandemic, it is likely that these data were subject to testing bias, suggesting in turn that the global COVID-19 associated surgical mortality is likely to have been confounded. Modern guidance on perioperative care has now placed significant emphasis on preadmission testing and re-testing during surgical admissions.[24] Guidelines have also been produced on the recommended intervals for performing elective surgery after COVID-19 infection,[29] a necessary requirement in view of the higher rate of pulmonary complications occurring with earlier intervention.[30] This guidance should be stringently followed to prevent future mortality in surgical cohorts through the application of timely, evidence based therapeutic interventions and prevention strategies.

In line with previous data, the PREDICT study has also shown several factors to be associated with worse clinical outcomes for emergency surgical patients during the pandemic. Higher Clinical Frailty Scale and ASA grades were strongly associated with increased in-hospital mortality. Higher Charlson Comorbidity Index scores and moderate CFS (3–4) were also associated with increased length of stay. In keeping with Hewitt et al,[31] who examined CFS amongst a cohort of 1564 COVID-19 patients, we found frailty was a better predictor of in-hospital mortality than total co-morbidities or factors including age. CFS may, therefore, aid surgeons in the risk-benefit assessment they must currently undertake when attempting patient risk stratification during the COVID-19 pandemic. Personalized COVID-19 frailty and morbidity assessments can help surgical healthcare professionals objectively determine need for inpatient admission, critical care support as well as the appropriateness of operative management.

Nonetheless, there are some inherent limitations associated with this study. Firstly, it is likely that not all eligible patients were identified over the course of the study period. This would be understandable in the context of the significant clinical pressure most units were facing under these unprecedented circumstances. In addition, some units suffered delays receiving ethical approval, which may have impacted their ability to complete their data set. To mitigate for these factors, iterative checks were performed to ensure data completeness and local investigators asked to validate entries before the data analysis phase of the study. Despite these measures and the best efforts of participating teams, we accept that our dataset does not capture the totality of emergency surgical presentations at participating centres during the study period. Although data was collected from 18 countries, the majority of the recruited patients are from the UK and mainland Europe (94 4% of this cohort of patients), which may limit the external validity of our findings. In particular, analysis pertaining to structures measures had to be limited to UK centers only. Although this analysis does provide a substantial perspective into the dynamic response to loco-regional burden within a single public health system, it may not be reflective of practice in all other health systems. Additionally, this study focusses solely on emergency surgical care, and therefore its findings cannot be applied to planned surgical care.

Finally, it is important to note that the COVID-19 prevalence in our cohort is most likely lower than the true rates within the surgical population. The underestimation of COVID-19 infection within a surgical population has been identified in other studies,[4,20] but also recognized at a population level by government organisations,[32] and is most likely due to the low testing rates and poorer testing methods earlier on in the pandemic.

Our findings support recommendations put forward by the PanSurg collaborative,[33] and other global surgical associations,[13] that suggest surgical practice and the surgical workforce should be protected to maintain the safety of surgical patients during the pandemic. It is imperative that both emergency and elective surgical services are maintained with appropriate biosecurity measures in place to ensure patient safety and that accurate patient risk stratification occurs using patient frailty assessment scores.

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