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Comparative Study - Retrospective Cohort

Use of failure-to-rescue after emergency surgery as a dynamic indicator of hospital resilience during the COVID-19 pandemic. A multicenter retrospective propensity score-matched cohort study

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A B S T R A C T

Background: Surgical failure-to-rescue (FTR, death rate following complications) is a reliable cross-sectional quality of care marker, but has not been evaluated dynamically. We aimed to study changes in FTR following emergency surgery during the COVID-19 pandemic.
Material and methods: Matched cohort study including all COVID-19-non-infected adult patients undergoing emergency general surgery in 25 Spanish hospitals during COVID-19 pandemic peak (March–April 2020), non-peak (May–June 2020), and 2019 control periods. A propensity score-matched comparative analysis was conducted using a logistic regression model, in which period was regressed on observed baseline characteristics. Subsequently, a mixed effects logistic regression model was constructed for each variable of interest. Main variable was FTR. Secondary variables were post-operative complications, readmissions, reinterventions, and length of stay.
Results: 5003 patients were included (948, 1108, and 2947 in the pandemic peak, non-peak, and control periods), with comparable clinical characteristics, prognostic scores, complications, reintervention, rehospitalization rates, and length of stay across periods. FTR was greater during the pandemic peak than during non-peak and pre-pandemic periods (22.5% vs. 17.2% and 12.7%), being this difference confirmed in adjusted analysis (odds ratio [OR] 2.13, 95% confidence interval [95% CI] 1.27–3.66). There was sensible inter-hospital variability in FTR changes during the pandemic peak (median FTR change +8.77%, IQR 0–29.17%) not observed during the pandemic non-peak period (median FTR change 0%, IQR -6.01−6.72%). Greater FTR increase was associated with higher COVID-19 incidence (OR 2.31, 95% CI 1.31–4.16) and some hospital characteristics, including tertiary level (OR 3.07, 95% CI 1.27–8.00), medium-volume (OR 2.79, 95% CI 1.14–7.34), and high basal-adjusted complication risk (OR 2.21, 95% CI 1.07–4.72).
Conclusion: FTR following emergency surgery experienced a heterogeneous increase during different periods of the COVID-19 pandemic, suggesting it to behave as an indicator of hospital resilience. FTR monitoring could facilitate identification of centres in special needs during ongoing health care challenges.

1. Introduction

The coronavirus disease 2019 (COVID-19) pandemic has strained the resources of health care systems worldwide, limiting their ability to respond to the health care needs of patients [1,2]. There is a need for scientific evidence to support the evaluation of resilience in health care in order to improve preparedness to pandemics and other challenges, and avoid preventable deaths in the future [3,4]. Given the critical role of hospitals in any health system, the model of “safe and resilient hospitals” has been promoted as a key component of disaster risk relief planning [5,6].

Hospital resilience is defined as the capacity of a hospital to adjust their functioning in order to maintain quality of care under changing conditions [7]. The evaluation of resilience has been largely based on data obtained from surveys, questionnaires and checklists measuring hospitals’ structures, resources, and services, with little attention to the real impact on clinical outcomes [8,9].

Surgical failure-to-rescue (FTR), the death rate following a postoperative complication, captures hospitals’ inability to stop the transition from an initial complication to the progressive cascade of adverse events that lead to death, and therefore has been widely used as an indicator of the quality of care in hospitals [10,11]. Whereas complications have been found to be primarily associated with underlying disease and patient characteristics, FTR has been primarily linked to hospital characteristics, such as centre volume, nurse-to-bed ratio, or the availability of specialty services (like gastroenterology or interventional radiology) [10,12]. This metric has been used in a static manner, eg, to assess differences in the quality of perioperative care across hospitals [13,14] and countries [11,15], but not dynamically to monitor changes over time in the same facilities or group of facilities. Longitudinal assessment of FTR could be useful in monitoring the ability of a given provider to respond to changing epidemiological and care delivery circumstances [16].

The present study aims to assess the resilience of Spanish hospitals over the COVID-19 pre-pandemic and pandemic periods focussing on the variation in FTR following emergency general surgery.

2. Material and methods

2.1. Study design and participants

A multicentre retrospective matched study of consecutive patients undergoing emergency general surgery during the first wave of the COVID-19 pandemic in Spanish hospitals was performed. Participant hospitals, which are responsible for >80% of emergency surgical volume of three Spanish autonomous communities (Catalonia, Basque Country, and Navarra), were selected based on their ability to contribute high quality data [17,18]. All patients aged 18 or more undergoing emergency gastrointestinal or general surgery (including emergency reinterventions for complications of elective surgery) during the pandemic and pre-pandemic periods in 25 participating hospitals (Table S1 in the Supplemental material) were included. The first procedure was considered as the index procedure when patients underwent multiple emergency operations. All COVID-19-positive patients (due to either a positive reverse transcription-polymerase chain reaction test of nasopharyngeal samples within 15 days before or 30 days after surgery, or COVID-19 infection confirmed by chest CT-scan in cases with a clinically compatible presentation) were excluded.

Four cohorts of patients were defined according to the date the eligible patient underwent emergency surgery: pandemic peak period (from March 1 to April 30, 2020); pandemic non-peak period (from May 1 to June 30, 2020); and two corresponding consecutive control periods stretching from March 1 to June 30, 2019 [19]. Pandemic and control patients were matched one-to-one based on propensity scores (Figure S1 in the Supplement). Due to the descriptive design of the study, formal calculation of the sample was not performed, being defined by the number of patients fulfilling inclusion criteria and complete data operated on during the study periods.

The study was conducted in accordance with the principles of the Declaration of Helsinki and data were reported following the recommendations of the STROCSS 2021 guideline [20]. Informed patient consent was waived given the retrospective nature of the study. Confidentiality was ensured in compliance with the provisions of personal data protection as required by Spanish Law (LOPD 3/2018). The study protocol (COVID-CIR) was registered in a research register (ClinicalT rials.gov, NCT04479150, July 21st, 2020, https://clinicaltrials.gov/ct2/show/NCT04479150), approved by the Institutional Review Board of participating hospitals (code PR169/20, date approval May 5th, 2020), and is available elsewhere [21]. The COVID-CIR project has been awarded a research grant, intended entirely for electronic Case Report Form design and statistical analysis.

2.2. Data collection, variables, and outcomes

2.2.1. Data collection

This study was based in the multicenter COVID-CIR registry, including data from electronic medical records by the participating hospitals (COVID-CIR Collaborative Group, fully detailed in Table S1, Supplemental material) [21]. Anonymized data were gathered in an electronic case record form with REDCap™ (Research Electronic Capture, Vanderbilt University, Nashville, Tennessee, USA) software.

The principal investigators (JO, ZM and SV) confirmed completeness and accuracy of data with principal investigators from each centre. Patients for which information was missing on key variables (age, sex, functional status, previous comorbidities, malignancy, COVID-19 infection status, date of surgery, clinical priority, type and complexity of surgery, and 30-day postoperative follow-up) were excluded.

2.2.2. Individual patient variables

Individual patient data included: age, sex, Body Mass Index (BMI), American Society of Anaesthesiologists (ASA) surgical risk score, and pre-existing comorbidities (hypertension, chronic obstructive pulmonary disease [COPD], diabetes, cardiovascular diseases, and others). Patients were classified according to their functional dependency (ability to perform daily life activities) in three categories: independent, partially dependent, and totally dependent, as defined by *Scarborough* et al. [22]. Pre-operative data collected on the same day of index surgery included: body temperature; blood pressure; heart rate; Glasgow coma score; electrocardiogram findings; and inflammatory analytical indexes (neutrophil/lymphocyte ratio [NLR], platelet/lymphocyte ratio [PLR], and Systemic Immune-inflammation Index [SII, neutrophil x platelet/lymphocyte counts]). Surgical variables included: access; malignancy (yes/no); type and extension of peritoneal exudates; and estimated blood loss. Complexity of surgical procedures was classified as minor, moderate, major, or major + using the POSSUM (Physiological and Operative Severity Score for the enUmeration of Mortality and Morbidity) scale [23]. Portsmouth-POSSUM (P-POSSUM) prognostic surgical scale was calculated [23,24]. Procedures were classified as: emergency, when needed within 2 h from admission; and urgent if needed within 24 h [23].

2.2.3. Hospital characteristics

The main hospital variable was the risk-adjusted complication rate across the control periods (2019). It was calculated using a multivariate logistic regression model in which the independent variables were patients' age, gender, current smoker, ASA, severity of surgery, surgical procedure category, and the presence of ischemic heart disease, heart failure, diabetes mellitus, COPD, cirrhosis, stroke, and other comorbid diseases. Risk-adjusted rates of complications were calculated from the predicted probabilities generated by this model during the non-pandemic periods and then used to rank hospitals into terciles [11].

Additionally, information was collected on number of beds (ranked into three terciles) and hospital level (primary, secondary, and tertiary, corresponding to increasing patient and procedure complexity, as determined by Spanish health authorities) [11].

2.2.4. Outcomes

The main outcome variable was failure-to-rescue (FTR), defined as the rate of patients with postoperative complications who died in the 30 first days after surgery (day 0 = day of the index surgery) [12]. Secondary outcomes were: any postoperative complication; a severe complication (defined as any complication graded IIIA or more with the Clavien-Dindo score) [25]; length of stay (number of days from admission to hospital discharge or death); ≤30-day hospital readmission; and ≤30-day surgical reintervention.

2.3. Statistical analysis

Patients' pre-operative and operative characteristics were summarized by period using standard descriptive statistics. 30-day cumulative incidence and 95% confident interval (95% CI) of each outcome were calculated in each surgery period.

Firstly, a propensity score-matched analysis was done using a logistic regression model, in which surgery period was regressed on observed baseline characteristics. Variables were prospectively selected based on clinical relevance [21]: age, sex, functional status, smoking status, hypertension, COPD, diabetes, cardiovascular diseases, malignancy, clinical priority, surgical complexity, need of Intensive Care Unit (ICU) before surgery, and hospital. Participants were matched for propensity score using a calliper width of 0.2 [26]. Standardized mean difference on observed baseline characteristics was estimated and plotted for the matched cohorts to identify any imbalances.

Secondly, a logistic regression model was used to estimate odds ratios (OR) to quantify the effect on each outcome of the pandemic peak period vs. the corresponding calendar control period, and also between pandemic non-peak period vs. the corresponding control period as part of the main analysis. No further adjustment was necessary given that all the relevant confounding variables had been used in calculation of the propensity score. This was subsequently repeated as stratified by: hospital risk-adjusted complication rate; hospital level; volume of beds; and COVID-19 incidence. We hypothesized that FTR would be raised over both pandemic periods (more so during peak periods, as hospital capacity would be particularly strained) in comparison with calendar control periods (over which we hypothesized FTR would be stable). We also hypothesized that FTR would raise even more for specific hospital categories: lower hospital level and volume (suggesting lower capacity for mobilising resources); higher risk-adjusted complication rate (already evidencing a higher basal likelihood of poorer outcomes); and for COVID-19 incidence in the reference population (due to increased pressure on services).

Thirdly, a mixed effects logistic regression model was used to estimate intraclass correlation coefficients (ICC) in order to quantify the hospital effect on FTR variability [27]. The model was estimated for each surgical period before and after applying propensity-matching.

All analyses were performed using R version 3.6.3 computer software [28]. Significance was defined as $p < 0.05$.

3. Results

3.1. Participant characteristics

Out of 5468 potentially eligible patients, 5003 COVID-19-negative patients fulfilled all the inclusion and data quality criteria: 948 were operated on during the pandemic peak-months (from March to April 2020), 1108 during the non-peak pandemic period (from May to June 2020), and 2947 patients during the pre-pandemic period (from March to June 2019).

Patients across all periods had similar clinical characteristics, as ICU admission before surgery, clinical priority and complexity of their surgical procedures, malignancy, peritonitis, analytical variables, and surgical prognostic scores, as detailed in Table 1. The percentage of patients according to selected hospital related variables (hospital level, size, and basal-adjusted complication rate) did not substantially differ across periods. Terciles of hospital-adjusted complication rates included approximately the same number of patients.

Table 1
Baseline characteristics of participants.

		Pandemic period (2020)		Control period (2019)	
		March–April (*peak*) n = 948	May–June (*non-peak*) n = 1108	March–April n = 1485	May–June n = 1462
Age, years	mean (SD)	54.7 (20.2)	55.8 (19.4)	56.0 (19.9)	56.0 (20.0)
	median (IQR)	55.0 (39.0–71.0)	56.5 (41.0–72.0)	57.0 (40.0–72.0)	57.0 (40.0–73.0)
Sex, No. (%)	Male	551 (58.1)	684 (61.7)	852 (57.4)	872 (59.6)
	Female	397 (41.9)	424 (38.3)	633 (42.6)	590 (40.4)
Weight, mean (SD), kg		74.6 (16.7)	76.7 (16.8)	75.2 (17.7)	75.3 (16.8)
BMI, mean (SD), kg/m2		26.9 (5.7)	27.5 (5.6)	27.2 (5.9)	27.4 (5.9)
Current smoking, No. (%)		171 (18.0)	195 (17.6)	264 (17.8)	244 (16.7)
ASA score, No. (%)	I	269 (28.5)	320 (29.1)	454 (30.8)	398 (27.4)
	II	393 (41.6)	452 (41.2)	571 (38.8)	565 (38.8)
	III	228 (24.2)	276 (25.1)	365 (24.8)	411 (28.2)
	IV	53 (5.6)	48 (4.4)	79 (5.4)	76 (5.2)
	V	1 (0.1)	2 (0.2)	4 (0.3)	5 (0.3)
Functional status[a], No. (%)	Independent	856 (90.3)	1008 (91.0)	1346 (90.6)	1345 (92.0)
	Partially dependent	84 (8.9)	93 (8.4)	129 (8.7)	99 (6.8)
	Totally dependent	8 (0.8)	7 (0.6)	10 (0.7)	18 (1.2)
Respiratory system, No. (%)	No dyspnea	835 (88.1)	1005 (90.8)	1360 (91.7)	1338 (91.5)
	Dyspnea	113 (11.9)	102 (9.2)	123 (8.3)	124 (8.5)
Cardiac system, No. (%)	No heart failure	769 (81.1)	852 (77.0)	1134 (76.4)	1081 (73.9)
	Diuretics, antihypertensives	153 (16.2)	224 (20.2)	302 (20.3)	327 (22.4)
	Heart failure, cardiomegaly	25 (2.6)	31 (2.8)	49 (3.3)	54 (3.7)
Comorbid diseases, No. (%)	Hypertension[b]	308 (32.5)	375 (33.8)	504 (33.9)	515 (35.2)
	Diabetes mellitus[b]	117 (12.3)	140 (12.6)	208 (14.0)	206 (14.1)
	COPD	81 (8.5)	91 (8.2)	92 (6.2)	102 (6.9)
	Arteriopathy	108 (11.4)	128 (11.6)	207 (13.9)	187 (12.8)
Malignancy, No. (%)	No	883 (93.1)	1026 (92.6)	1396 (94.0)	1351 (92.4)
	Localized tumour	36 (3.8)	48 (4.3)	49 (3.3)	75 (5.1)
	Metastatic tumour	29 (3.1)	34 (3.1)	40 (2.7)	36 (2.5)
ICU before surgery, No. (%)	No	919 (96.9)	1067 (96.5)	1430 (96.4)	1380 (94.7)
	Due to surgical pathology	22 (2.3)	31 (2.8)	40 (2.7)	54 (3.7)
	Due to other causes	7 (0.7)	8 (0.7)	14 (0.9)	24 (1.7)
Glasgow coma scale, mean (SD), score		14.9 (0.9)	14.9 (1.1)	14.9 (0.8)	14.9 (1.2)
Analytical inflammatory markers, median (IQR)	NLR	7.1 (3.8–12.0)	6.8 (3.8–12.2)	6.7 (3.8–12.4)	6.7 (3.7–11.8)
	PLR	168 (114–268)	169 (114–260)	175 (110–274)	168 (111–264)
	SII, x109/L	1706 (852–3146)	1587 (895–3030)	1619 (867–3098)	1538 (862–2842)
	C-reactive protein, mg/L	49.0 (10.8–139.0)	50.5 (12.0–155.0)	49.0 (11.1–148.0)	52.7 (12.0–156.0)
	Procalcitonine, ng/mL	0.4 (0.1–2.9)	0.4 (0.1–1.9)	0.6 (0.1–2.9)	0.5 (0.1–2.7)
Surgical priority, No. (%)	Urgent (>2 h, <24 h)	905 (95.5)	1055 (95.2)	1403 (94.5)	1365 (93.4)
	Emergency (<2 h)	43 (4.5)	53 (4.8)	82 (5.5)	97 (6.6)
Surgical complexity[c], No. (%)	Minor	219 (23.1)	247 (22.3)	398 (26.8)	367 (25.1)
	Intermediate	447 (47.2)	573 (51.7)	681 (45.9)	689 (47.1)
	Major	259 (27.3)	260 (23.5)	372 (25.1)	351 (24.0)
	Major +	23 (2.4)	28 (2.5)	34 (2.3)	55 (3.8)
Emergency laparotomy (NELA definition criteria)[d], No. (%)		249 (26.3)	248 (22.4)	364 (24.5)	367 (25.1)
Laparoscopic surgery, No. (%)		415 (43.8)	569 (51.4)	669 (45.1)	638 (43.6)
Peritoneal exudate, No. (%)	No	462 (48.7)	489 (44.2)	780 (52.5)	725 (49.6)
	Serous	215 (22.7)	252 (22.8)	303 (20.4)	297 (20.3)
	Localized pus	172 (18.1)	250 (22.6)	252 (17.0)	285 (19.5)
	Diffuse peritonitis	99 (10.4)	116 (10.5)	150 (10.1)	155 (10.6)
Surgical blood loss, No. (%)	≤100 mL	829 (87.4)	966 (87.3)	1276 (86.0)	1236 (84.6)
	101–500 mL	103 (10.9)	112 (10.1)	168 (11.3)	154 (10.5)
	501–1000 mL	7 (0.7)	20 (1.8)	14 (0.9)	32 (2.2)
	>1000 mL	9 (0.9)	9 (0.8)	26 (1.8)	39 (2.7)
P-POSSUM[e], score	mean (SD)	4.3 (10.7)	4.1 (9.9)	4.1 (9.6)	4.6 (10.1)
	median (IQR)	1.1 (0.6–2.9)	1.0 (0.6–3.1)	1.1 (0.6–2.9)	1.1 (0.6–2.9)

SD: standard deviation; IQR: interquartile range; BMI: body mass index; ASA: American Society of Anesthesiologists; COPD: chronic obstructive pulmonary disease; ICU: intensive care unit; NLR: Neutrophil/Lymphocyte Ratio; PLR: Platelet/Lymphocyte Ratio; SII: Systemic Immune-inflammation Index (neutrophil x platelet/lymphocyte counts); NELA: National Emergency Laparotomy Audit of England and Wales; P-POSSUM: Portsmouth-POSSUM scoring.

[a] As categorized by *Scarborough JE* et al. [22].

[b] Arterial hypertension and diabetes, defined as patient needing specific pharmacological treatment.

[c] Complexity of surgical procedure was considered as minor, moderate, major or major + as defined originally in the POSSUM score [23].
[d] Emergency laparotomy following the inclusion and exclusion criteria specified by the National Emergency Laparotomy Audit (NELA) [45].
[e] Portsmouth-POSSUM scoring [24].

3.2. Overall FTR across study periods

A total of 1257 (24.7%) patients developed complications, and 194 (3.8%) of them died during the 30 first days after surgery (global FTR 15.4%). Patients operated on during the pandemic peak-months had higher FTR than those operated on during non-peak months and than pre-pandemic controls (22.5% vs. 17.2% vs. 12.7%), with similar complication, reintervention, and rehospitalization rates and comparable length of stay (Table 2). Adjusted analysis confirmed the FTR increase during the peak pandemic period (Fig. 1) .

A total of 943 patients from pandemic peak-months and 1091 patients from pandemic non-peak months were matched with 943 and 1091 patients operated on during the same calendar period in the previous year, respectively, for the propensity-score analysis (Figure S1 in the Supplement). During the pandemic peak, FTR was significantly higher than in the corresponding control period (adjusted OR 2.13, 95% CI 1.27–3.66), while no differences in complications nor severe complication risk were observed (Table 3). No significant differences in FTR, complications or severe complications were observed between the non-peak pandemic period and the corresponding calendar control period.

The hospital ICC after propensity score-matching was, in general terms, low. It was consistently low and stable in the pandemic peak period (0.06), and was lower and suffered a further reduction after matching for the non-peak period (Table 4). The existence of an ICC close to 0 suggest that the context defined by the hospital is not that relevant in understanding subject health outcomes [27].

3.3. Inter-hospital variability

There was sensible inter-hospital variability in FTR changes from 2019 to 2020 calendar period during the pandemic peak (median FTR change +8.77%, IQR 0–29.17%) that was not observed during the pandemic non-peak period (median FTR change 0%, IQR -6.01 to 6.72%) (Figure S2 in the Supplement).

Hospital characteristics associated with higher FTR increase in relation to the pandemic peak period were: tertiary level (adjusted OR 3.07, 95% CI 1.27–8.00), medium-volume (OR 2.79, 95% CI 1.14–7.34), and high basal-adjusted complication risk (OR 2.21, 95% CI 1.07–4.72) (Fig. 2a). Confidence intervals for all categories of all hospital-level variables, however, overlapped across all categories for all variables. Hospital characteristics were not associated with changes to FTR in the pandemic non-peak period (Fig. 2b), neither to any complication risk change (Figure S3 in the Supplement).

While variation in the distribution of changes in FTR across different hospitals during the pandemic peak-months (vs. the corresponding calendar control period) was observed, no hospital exceeded the expected level of variation (Figure S2 in the Supplement).

4. Discussion

In this multicentre study of COVID-19-non infected patients undergoing emergency general surgery we found an adjusted two-fold increase of FTR during the pandemic peak compared with a control period in the previous year. To our knowledge, this is the first study using FTR as a dynamic marker, comparing different periods for the same set of hospitals under varying epidemiological contexts.

There is an extensive literature on the suitability of FTR as a hospital care quality indicator [10–12,29–31]. Factors such as outdated communication technology, lack of available specialty services (like interventional gastroenterology or radiology), nurse understaffing, and communication errors have all been identified as root causes of delay in detection of morbidity and therapeutic escalation [10–12,31]. During the COVID-19 pandemic, and particularly at its first peak, the health system in Spain may have found it very difficult to mobilise human and material resources. In addition, the ability of the system to recognize postoperative patients in distress and respond quickly and effectively may have been impaired due to work overload. Finally, the attitudes, subjective norms, and perceived control over environment of caregivers from the ICU, inpatient wards, and rapid response teams may be critically affected. It may be worth noting that the Spanish Health System may have been particularly vulnerable to the stress test of the COVID-19 pandemic due to austerity measures implemented since the 2008 financial crisis [3,32].

Most resilience markers proposed to date are qualitative [9,33,34], subjective [9,33,35,36], and/or measuring structural features or pathways (such as waiting time in the Emergency Department or length of stay) instead of clinical outcomes [9,33,35–39]. There is a need for resilience indicators based on simple, objective, and quantitative measures of patient-level clinical outcomes [1,3,5]. A range of outcome measures appear to lack the expected sensitivity to change: overall postoperative complications, severe complications, length of hospital

Table 2
Surgical outcomes by study period (unadjusted).

		March–April			May–June		
		2020 (peak) n = 948	2019 (non-peak months) n = 1485	p value	2020 (non-peak) n = 1108	2019 (non-peamonths) n = 1462	p value
Failure-to-rescue, %		22.5	12.7	0.002	17.2	12.7	0.143
Postoperative complications (overall), No. (%)		231 (24.4)	363 (24.4)	1.000	262 (23.7)	378 (25.9)	0.216
Complication type	Pulmonary, No. (%)	65 (6.9)	71 (4.8)	0.037	53 (4.8)	89 (6.1)	0.178
	Thromboembolic, No. (%)	16 (1.7)	15 (1.0)	0.205	21 (1.9)	23 (1.6)	0.638
	Other medical, No. (%)	92 (9.7)	139 (9.4)	0.832	113 (10.2)	162 (11.1)	0.514
	Surgical, No. (%)	142 (15.0)	260 (17.5)	0.114	176 (15.9)	249 (17.0)	0.471
Severe complications[a], No. (%)		124 (13.1)	181 (12.2)	0.662	121 (10.9)	177 (12.1)	0.434
30-day mortality, No. (%)		52 (5.5)	46 (3.1)	0.005	45 (4.1)	48 (3.3)	0.347
Surgical reintervention (≤30 days from index surgery date), No. (%)		52 (5.8)	78 (5.5)	0.814	55 (5.2)	72 (5.1)	1.000
Hospitalization length, median (IQR), days		4 (2–8)	4 (2–9)	0.130	4 (2–8)	4 (2–9)	0.011
Rehospitalization (≤30 days from index discharge date), No. (%)		62 (6.9)	82 (5.8)	0.300	67 (6.3)	106 (7.5)	0.277

IQR: interquartile range.
Postoperative complications with Clavien-Dindo grade ≥ IIIA [25].

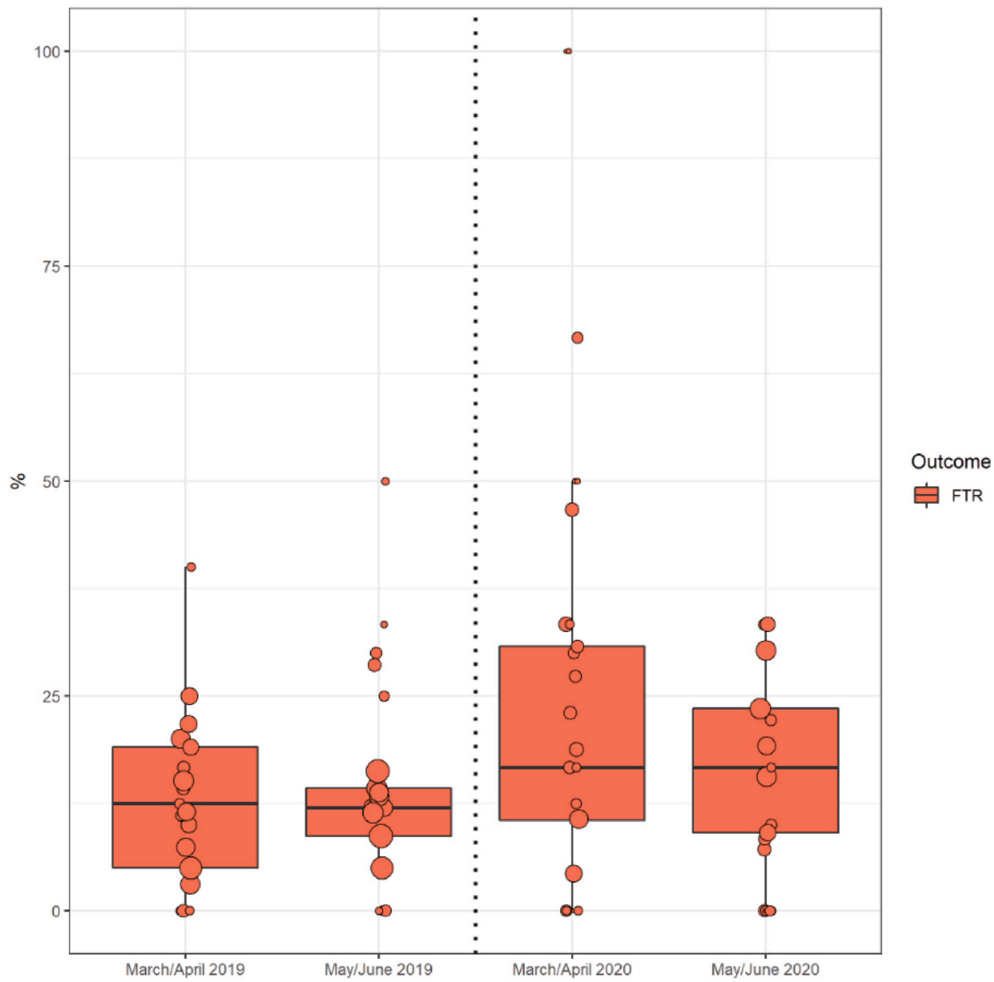

Fig. 1. Box plot[a] for failure-to-rescue in pandemic (peak and non-peak) and calendar control periods.
FTR: failure-to-rescue.
a Each dot represents a hospital. Dot's area is proportional to the number of cases included by each hospital.

Table 3
Association between study period and surgical outcomes in propensity-score-matched cohorts[a].

	OR	95% CI	p value
Pandemic (peak) vs. corresponding control (reference category)			
Failure-to-rescue	2.13	1.27–3.66	0.005
Complications	1.11	0.90–1.38	0.325
Severe complications[b]	1.22	0.93–1.62	0.157
Pandemic (non-peak) vs. corresponding control (reference category)			
Failure-to-rescue	1.47	0.87–2.49	0.149
Complications	0.98	0.81–1.20	0.879
Severe complications[b]	1.04	0.79–1.37	0.777

OR: odds ratio; 95% CI: 95% confident interval.
[a] Matching variables: sex, age, functional status, smoking status, hypertension, COPD, diabetes, cardiovascular diseases, malignancy, clinical priority, surgical complexity, and complications during surgery.
[b] Clavien-Dindo grade ≥ IIIA [25].

Table 4
Mixed effects logistic models for failure-to-rescue: before and after propensity-matching in peak period, and before and after propensity-matching in non-peak period.

Pandemic peak period vs. control period					
Failure-to-rescue	N	OR	95% CI	p value	ICC
Before propensity-matching	594	2.07	1.32–3.23	0.001	0.06
After propensity-matching	426	2.20	1.28–3.77	0.004	0.06
Pandemic non-peak period vs. control period					
Failure-to-rescue	**N**	**OR**	**95% CI**	**p value**	**ICC**
Before propensity-matching	625	1.41	0.90–2.22	0.136	0.03
After propensity-matching	484	1.45	0.85–2.46	0.168	0.01

OR: odds ratio; 95% CI: 95% confident interval; ICC: intraclass correlation coefficient [27].

stay, and readmissions, for instance, were not significantly altered in our study. FTR is an interpretable and relevant clinical outcome that is easy to calculate and that may be reported in a continuous manner to help detecting critical periods of poorer adaptability of the hospital care system. Even though elective surgeries may be suspended or delayed in some stressful circumstances, most emergency surgeries are not avoidable without a considerable risk for the patient. Therefore, FTR changes following emergency surgery may be monitored even during health crisis such as the COVID-19 pandemic.

We identified sensitive differences in FTR changes among hospitals during the pandemic peak that cannot be explained by patient case-mix. The adjusted complication risk significantly correlated with FTR, suggesting that centres with higher risk of complications during the baseline period were also the least resilient during the COVID-19 pandemic. We also observed a trend towards bigger and more complex hospitals presenting a larger FTR increase, suggesting they had more difficulties delivering optimal care in this stressful context. Contrary to previous reservations about the performance of FTR as an indicator in hospitals

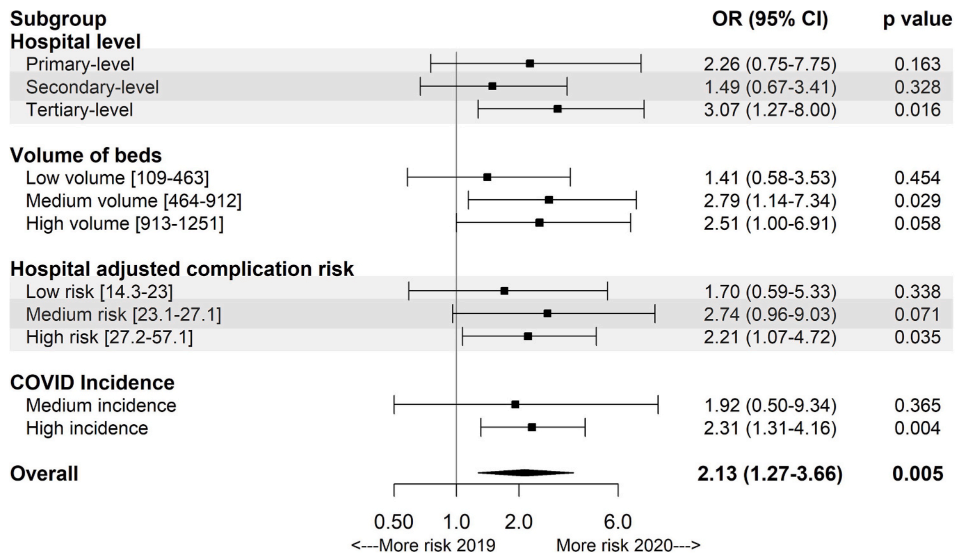

Fig. 2a. Failure-to-rescue propensity-score-matched comparison of pandemic vs. pre-pandemic periods across different hospital categories (including COVID-19 incidence in the reference population). Pandemic peak vs. calendar control

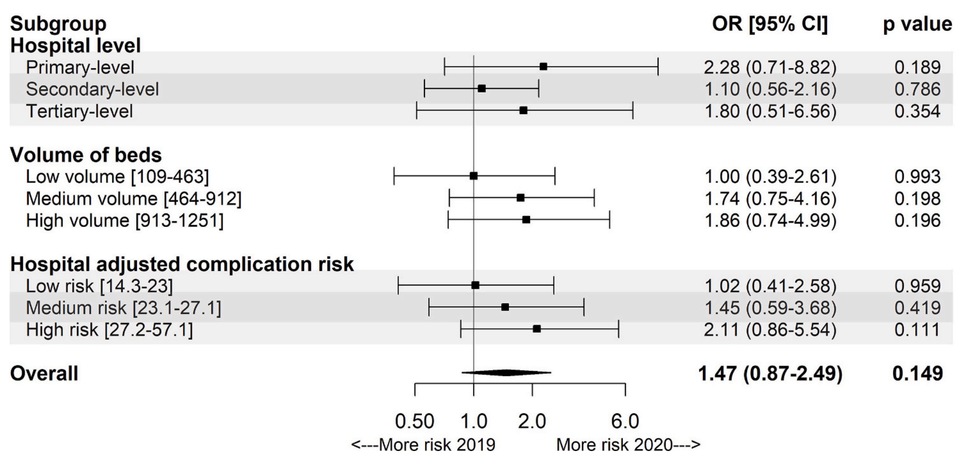

Fig. 2b. Failure-to-rescue propensity-score-matched comparison of pandemic vs. pre-pandemic periods across different hospital categories (including COVID-19 incidence in the reference population). Pandemic non-peak vs. calendar control.
COVID-19: coronavirus disease 2019; OR: odds ratio; 95% CI: 95% confident interval.

with a low complication rate [40], the overall complication rate remained unchanged during the pandemic peak.

One of the main shortcomings of improvement programmes focused on prevention of complications is that operations are associated with an intrinsic rate of morbidity [10,11]. For example, improved adherence to protocols designed to prevent surgical site infections or venous thromboembolisms were not translated into better outcomes [41–44]. By comparison, when considering prevention of FTR, there is a clear potential action point in the postoperative care pathway - the early identification of complications and the institution of appropriate rescue therapy [10].

This study has some limitations. Generalizability is compromised as it was conducted in a single country. Replication in other countries would be advisable. The NELA (National Emergency Laparotomy Audit) register from England and Wales [45], for example, could be useful to benchmark our findings, but it could not be used as it does not include postoperative complications data. In addition, temporal series longer than the ones included in our study would be needed to appraise the stability of FTR estimates over periods of time in which the system is not subjected to additional stress. The retrospective design is a further limitation, which was intended to be minimized by the thorough data quality control, the exclusion of patients with relevant missing variables, and the adjusted analysis. Finally, propensity score adjustment cannot balance for unknown or known unmeasured confounding variables.

5. Conclusions

This large multicentre propensity-score matched study provides evidence of differences in FTR following emergency general surgery in relation to key time periods defined by the COVID-19 pandemic. Failure-to-rescue is a promising metric for the assessment of resilience of health systems in the face of significant health challenges.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Data statement

All raw data used in this study are available and will be provided by Javier Osorio, Zoilo Madrazo, Sebastián Videla, and Cristian Tebe, under sensible demand.

CRediT authorship contribution statement

Javier Osorio: Conceptualization, Funding acquisition, Data curation, Investigation, Methodology, Validation, Visualization, Writing – original draft, preparation, Writing – review & editing. **Zoilo Madrazo:** Conceptualization, Data curation, Investigation, Methodology, Validation, Visualization, Writing – original draft, preparation, Writing – review & editing. **Sebastian Videla:** Conceptualization, Methodology, Validation, Resources, Writing – original draft, preparation, Writing – review & editing. **Beatriz Sainz:** Investigation. **Araceli Rodríguez-Gonzalez:** Investigation. **Andrea Campos:** Investigation. **Maite Santamaria:** Investigation. **Amalia Pelegrina:** Investigation. **Carmen Gonzalez-Serrano:** Investigation. **Aurora Aldeano:** Investigation. **Aingeru Sarriugarte:** Investigation. **Carlos Javier Gómez-Díaz:** Investigation. **David Ruiz-Luna:** Investigation. **Amador García-Ruiz-de-Gordejuela:** Investigation. **Concepción Gomez-Gavara:** Investigation. **Marta Gil-Barrionuevo:** Investigation. **Marina Vila:** Investigation. **Arantxa Clavell:** Investigation. **Beatriz Campillo:** Investigation. **Laura Millan:** Investigation. **Carles Olona:** Investigation. **Sergi Sanchez-Cordero:** Investigation. **Rodrigo Medrano:** Investigation. **Camilo Andrés Lopez-Arevalo:** Investigation. **Noelia Pérez-Romero:** Investigation. **Eva Artigau:** Investigation. **Miguel Calle:** Investigation. **Víctor Echenagusia:** Investigation. **Aurema Otero:** Investigation. **Cristian Tebe:** Data curation, Formal analysis, Methodology, Software, Writing – original draft, preparation. **Natàlia Pallares:** Data curation, Formal analysis, Methodology, Software, Writing – original draft, preparation. **Sebastiano Biondo:** Conceptualization, Supervision. **Jose Maria Valderas:** Conceptualization, Supervision.

Declaration of competing interest

The authors have no competing interests to declare.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.ijsu.2022.106890.

References

[1] C. Sohrabi, Z. Alsafi, N. O'Neill, et al., World health organization declares global emergency: a review of the 2019 novel coronavirus (COVID-19), Int. J. Surg. 76 (2020) 71–76, https://doi.org/10.1016/j.ijsu.2020.02.034.
[2] M. Nicola, Z. Alsafi, C. Sohrabi, et al., The socio-economic implications of the coronavirus pandemic (COVID-19): a review, Int. J. Surg. 78 (2020) 185–193, https://doi.org/10.1016/j.ijsu.2020.04.018.
[3] A. García-Basteiro, C. Alvarez-Dardet, A. Arenas, et al., The need for an independent evaluation of the COVID-19 response in Spain, Lancet 396 (2020) 529–530, https://doi.org/10.1016/S0140-6736(20)31713-X.
[4] M. Nicola, N. O'Neill, C. Sohrabi, M. Khan, M. Agha, R. Agha, Evidence based management guideline for the COVID-19 pandemic - review article, Int. J. Surg. 77 (2020) 206–216, https://doi.org/10.1016/j.ijsu.2020.04.001.
[5] International Strategy for Disaster Reduction, Hyogo framework for action 2005–2015: building the resilience of nations and communities to disasters, in: World Conference on Disaster Reduction, 18–22 January 2005, Kobe, Hyogo, Japan, 2005. https://www.unisdr.org/2005/wcdr/intergover/official-doc/L-docs/Hyogo-framework-for-action-english.pdf. (Accessed 11 May 2022). accessed.
[6] World Health Organization, Department of Health Action in Crises, Annual Report, 2005. https://reliefweb.int/report/world/health-action-crises-annual-report-2005. (Accessed 11 May 2022), 2005.
[7] J. Braithwaite, R.L. Wears, E. Hollnagel, Resilient health care: turning patient safety on its head, Int. J. Qual. Health Care 27 (2015) 418–420, https://doi.org/10.1093/intqhc/mzv063.
[8] S. Fallah-Aliabadi, A. Ostadtaghizadeh, A. Ardalan, F. Fatemi, B. Khazai, M. R. Mirjalili, Towards developing a model for the evaluation of hospital disaster resilience: a systematic review, BMC Health Serv. Res. 20 (2020) 64, https://doi.org/10.1186/s12913-020-4915-2.
[9] S. Zhong, M. Clark, X.Y. Hou, Y.L. Zang, G. Fitzgerald, Development of hospital disaster resilience: conceptual framework and potential measurement, Emerg. Med. J. 31 (2014) 930–938, https://doi.org/10.1136/emermed-2012-202282.
[10] J.I. Portuondo, S.R. Shah, H. Singh, N.N. Massarweh, Failure to rescue as a surgical quality indicator: current concepts and future directions for improving surgical outcomes, Anesthesiology 131 (2019) 426–437, https://doi.org/10.1097/ALN.0000000000002602.
[11] T. Ahmad, R.A. Bouwman, I. Grigoras, et al., Use of failure-to-rescue to identify international variation in postoperative care in low-, middle- and high-income countries: a 7-day cohort study of elective surgery, Br. J. Anaesth. 119 (2017) 258–266, https://doi.org/10.1093/bja/aex185.
[12] M. Johnston, S. Arora, O. Anderson, D. King, N. Behar, A. Darzi, Escalation of care in surgery: a systematic risk assessment to prevent avoidable harm in hospitalized patients, Ann. Surg. 261 (2015) 831–838, https://doi.org/10.1097/SLA.0000000000000762.
[13] N.R.A. Symons, K. Moorthy, A.M. Almoudaris, et al., Mortality in high-risk emergency general surgical admissions, Br. J. Surg. 100 (2013) 1318–1325, https://doi.org/10.1002/bjs.9208.
[14] A.A. Ghaferi, J.D. Birkmeyer, J.B. Dimick, Variation in hospital mortality associated with inpatient surgery, N. Engl. J. Med. 361 (2009) 1368–1375, https://doi.org/10.1056/NEJMsa0903048.
[15] R.M. Pearse, R.P. Moreno, P. Bauer, et al., Mortality after surgery in Europe: a 7-day cohort study, Lancet 380 (2012) 1059–1065, https://doi.org/10.1016/S0140-6736(12)61148-9.
[16] J. Osorio, Z. Madrazo, S. Videla, et al., Analysis of outcomes of emergency general and gastrointestinal surgery during the COVID-19 pandemic, Br. J. Surg. 108 (2021) 1438–1447, https://doi.org/10.1093/bjs/znab299.
[17] W. Allum, J. Osorio, EURECCA oesophago-gastric cancer Project, Cir. Esp. 94 (2016) 255–256, https://doi.org/10.1016/j.ciresp.2015.12.005.
[18] M.D. Cero, J. Rodríguez-Santiago, M. Miró, et al., Evaluation of data quality in the Spanish EURECCA esophagogastric cancer registry, Eur. J. Surg. Oncol. 47 (2021) 3081–3087, https://doi.org/10.1016/j.ejso.2021.04.025.
[19] J. Winter Beatty, J.M. Clarke, V. Sounderajah, et al., Impact of the COVID-19 pandemic on emergency adult surgical patients and surgical services: an international multi-center cohort study and department survey, ann, Surgery 274 (2021) 904–912, https://doi.org/10.1097/SLA.0000000000005152.
[20] G. Mathew, R. Agha, For the STROCSS Group. STROCSS 2021: strengthening the Reporting of cohort, cross-sectional and case-control studies in Surgery, Int. J. Surg. 96 (2021), 106165, https://doi.org/10.1016/j.ijsu.2021.106165.
[21] Z. Madrazo, J. Osorio, A. Otero, S. Biondo, S. Videla, COVID-CIR Collaborative Group, Postoperative complications and mortality following emergency digestive surgery during the COVID-19 pandemic: a multicenter collaborative retrospective cohort study protocol (COVID-CIR), Medicine (Baltimore) 100 (2021), e24409, https://doi.org/10.1097/MD.0000000000024409.
[22] J.E. Scarborough, K.M. Bennett, B.R. Englum, T.N. Pappas, S.A. Lagoo-Deenadayalan, The impact of functional dependency on outcomes after complex general and vascular surgery, Ann. Surg. 261 (2015) 432–437, https://doi.org/10.1097/SLA.0000000000000767.
[23] M.S. Whiteley, D.R. Prytherch, B. Higgins, P.C. Weaver, W.G. Prout, An evaluation of the POSSUM surgical scoring system, Br. J. Surg. 83 (1996) 812–815, https://doi.org/10.1002/bjs.1800830628.
[24] D.R. Prytherch, M.S. Whiteley, B. Higgins, P.C. Weaver, W.G. Prout, S.J. Powell, POSSUM and Portsmouth POSSUM for predicting mortality. Physiological and operative severity score for the enUmeration of mortality and morbidity, Br. J. Surg. 85 (1998) 1217–1220, https://doi.org/10.1046/j.1365-2168.1998.00840.x.
[25] P.A. Clavien, J. Barkun, M.L. de Oliveira, et al., The Clavien-Dindo classification of surgical complications: five-year experience, Ann. Surg. 250 (2009) 187–196, https://doi.org/10.1097/SLA.0b013e3181b13ca2.
[26] P.C. Austin, Optimal caliper widths for propensity-score matching when estimating differences in means and differences in proportions in observational studies, Pharmaceut. Stat. 10 (2011) 150–161, https://doi.org/10.1002/pst.433.
[27] J. Merlo, M. Yang, B. Chaix, J. Lynch, L. Råstam, A brief conceptual tutorial on multilevel analysis in social epidemiology: investigating contextual phenomena in different groups of people, J. Epidemiol. Community Health 59 (2005) 729–736, https://doi.org/10.1136/jech.2004.023929.
[28] R Core Team, R: A Language and Environment for Statistical Computing, R Foundation for Statistical Computing, Vienna, Austria, 2021. https://www.R-project.org/. (Accessed 11 May 2022), 2021.
[32] The Lancet Public Health, COVID-19 in Spain: a predictable storm? Lancet Public Health 5 (2020) e568, https://doi.org/10.1016/S2468-2667(20)30239-5.
[33] J.E. Anderson, K. Aase, R. Bal, et al., Multilevel influences on resilient healthcare in six countries: an international comparative study protocol, BMJ Open 10 (2020), e039158, https://doi.org/10.1136/bmjopen-2020-039158.
[34] EU Expert Group on Health Systems Performance Assessment (HSPA), Assessing the Resilience of Health Systems in Europe: an Overview of the Theory, Current Practice and Strategies for Improvement, Publications Office of the EU, Luxembourg, 2020. https://ec.europa.eu/health/system/files/2021-10/2020_resilience_en_0.pdf. (Accessed 11 May 2022). accessed.

[35] G.A. Shirali, S.h. Azadian, A. Saki, A new framework for assessing hospital crisis management based on resilience engineering approach, Work 54 (2016) 435–444, https://doi.org/10.3233/WOR-162329.
[36] S.K. Sharma, N. Sharma, Hospital preparedness and resilience in public health emergencies at district hospitals and community health centres, J. Health Manag. 22 (2020) 146–156, https://doi.org/10.1177/0972063420935539.
[37] S. Zhong, M. Clark, X.Y. Hou, Y. Zang, G. FitzGerald, Development of key indicators of hospital resilience: a modified Delphi study, J. Health Serv. Res. Pol. 20 (2015) 74–82, https://doi.org/10.1177/1355819614561537.
[38] M. Moitinho de Almeida, J.A.F. van Loenhout, S.S. Thapa, et al., Clinical and demographic profile of admitted victims in a tertiary hospital after the 2015 earthquake in Nepal, PLoS One 14 (2019), e0220016, https://doi.org/10.1371/journal.pone.0220016.
[39] G.P. Cimellaro, M. Malavisi, S. Mahin, Using discrete event simulation models to evaluate resilience of an emergency department, J. Earthq. Eng. 21 (2017) 203–226, https://doi.org/10.1080/13632469.2016.1172373.
[40] D. Altan, G.A. Leya, D.C. Chang, Tracking the "end result" and long-term patient outcomes–failure to rescue and the shrinking denominator, JAMA Surg 157 (2022) 268, https://doi.org/10.1001/jamasurg.2021.6905.
[41] J.J. Stulberg, C.P. Delaney, D.V. Neuhauser, D.C. Aron, P. Fu, S.M. Koroukian, Adherence to surgical care improvement project measures and the association with postoperative infections, JAMA 303 (2010) 2479–2485, https://doi.org/10.1001/jama.2010.841.
[42] M.T. Hawn, C.C. Vick, J. Richman, et al., Surgical site infection prevention: time to move beyond the surgical care improvement program, Ann. Surg. 254 (2011) 494–499, https://doi.org/10.1097/SLA.0b013e31822c6929.
[43] K.Y. Bilimoria, J. Chung, M.H. Ju, et al., Evaluation of surveillance bias and the validity of the venous thromboembolism quality measure, JAMA 310 (2013) 1482–1489, https://doi.org/10.1001/jama.2013.280048.
[44] B.D. Lau, M.B. Streiff, P.J. Pronovost, E.R. Haut, Venous thromboembolism quality measures fail to accurately measure quality, Circulation 137 (2018) 1278–1284, https://doi.org/10.1161/CIRCULATIONAHA.116.026897.
[45] NELA Project Team, The Impact of COVID-19 on Emergency Laparotomy–An Interim Report of the National Emergency Laparotomy Audit, 23 March 2020–30 September 2020, Royal College of Anaesthetists, London, 2021. https://www.nela.org.uk/downloads/COVID_analysis_08%20Mar%202021.pdf. (Accessed 11 May 2022). accessed.