Cancelled operations: a 7-day cohort study of planned adult inpatient surgery in 245 UK National Health Service hospitals.

D J N Wong

S K Harris

S R Moonesinghe

Thomas A. McLoughlin

BJA

British Journal of Anaesthesia, 121 (4): 730–738 (2018)

doi: 10.1016/j.bja.2018.07.002
Advance Access Publication Date: 7 September 2018
Clinical Practice

CLINICAL PRACTICE

Cancelled operations: a 7-day cohort study of planned adult inpatient surgery in 245 UK National Health Service hospitals

D. J. N. Wong[1,2,*], S. K. Harris[3], S. R. Moonesinghe[1,2] on behalf of the SNAP-2: EPICCS collaborators[§]

[1]Health Services Research Centre, National Institute of Academic Anaesthesia, Royal College of Anaesthetists, London, UK, [2]UCL/UCLH Surgical Outcomes Research Centre (SOuRCe), Centre for Perioperative Medicine, Department for Targeted Intervention, Division of Surgery and Interventional Science, University College London, London, UK and [3]Bloomsbury Institute of Intensive Care Medicine, University College London, London, UK

*Corresponding author. E-mail: dwong@rcoa.ac.uk

[§]A full list of collaborators and their affiliations is included in the Supplementary Material.

This article is accompanied by an editorial: Counting the cost of cancelled surgery: a system wide approach is needed by Gillies et al., *Br J Anesth* 2018:121:691–694, doi: 10.1016/j.bja.2018.08.002.

Abstract

Background: Cancellation of planned surgery impacts substantially on patients and health systems. This study describes the incidence and reasons for cancellation of inpatient surgery in the UK NHS.

Methods: We conducted a prospective observational cohort study over 7 consecutive days in March 2017 in 245 NHS hospitals. Occurrences and reasons for previous surgical cancellations were recorded. Using multilevel logistic regression, we identified patient- and hospital-level factors associated with cancellation due to inadequate bed capacity.

Results: We analysed data from 14 936 patients undergoing planned surgery. A total of 1499 patients (10.0%) reported previous cancellation for the same procedure; contemporaneous hospital census data indicated that 13.9% patients attending inpatient operations were cancelled on the day of surgery. Non-clinical reasons, predominantly inadequate bed capacity, accounted for a large proportion of previous cancellations. Independent risk factors for cancellation due to inadequate bed capacity included requirement for postoperative critical care [odds ratio (OR)=2.92; 95% confidence interval (CI), 2.12–4.02; $P<0.001$] and the presence of an emergency department in the treating hospital (OR=4.18; 95% CI, 2.22–7.89; $P<0.001$). Patients undergoing cancer surgery (OR=0.32; 95% CI, 0.22–0.46; $P<0.001$), obstetric procedures (OR=0.17; 95% CI, 0.08–0.32; $P<0.001$), and expedited surgery (OR=0.39; 95% CI, 0.27–0.56; $P<0.001$) were less likely to be cancelled.

Editorial decision: 9 July 2018; **Accepted:** 9 July 2018

Conclusions: A significant proportion of patients presenting for surgery have experienced a previous cancellation for the same procedure. Cancer surgery is relatively protected, but bed capacity, including postoperative critical care requirements, are significant risk factors for previous cancellations.

Keywords: Health Services Research; medical resource utilisation; operating room management; surgery

Editor's key points

- Last-minute cancellations of elective surgical procedures negatively impact patient experience and outcomes and health system function and efficiency.
- A prospective observational cohort study conducted over 1 week in March 2017 in 245 UK NHS hospitals analysed occurrences and reasons for surgical cancellations.
- One in 10 patients presenting for surgery experienced a previous cancellation largely for non-clinical reasons including bed capacity and postoperative critical care requirements.

Last-minute cancellation of surgery can have significant adverse consequences on patient experiences and outcomes.[1–3] In the UK, operational pressures faced by the National Health Service (NHS) feature prominently in news reports and the medical literature, especially during the winter season when there is an increased rate of emergency admissions.[4,5] During the 2017–8 winter, NHS England went so far as to recommend that all hospitals cancel elective surgery during January to mitigate against the competing pressure on emergency services.[6] Cancellations are, however, not just a winter problem, and may be attributable to other factors including unexpected changes in health affecting fitness for surgery, inadequate patient preparation, and logistical reasons such as staffing issues or equipment failure.[7–13] Elective surgical cancellation rates appear to be rising, even after accounting for seasonal fluctuations.[14]

The rates of surgical cancellations attributable to different risk factors are not known: current collated reports of cancellations at a national level do not record causes, and studies that have looked at this issue have predominantly small samples or are single-centre evaluations.[7–13] We therefore undertook a national study to explore the incidence of cancellations and risk factors for cancellation at patient and hospital level. We focused on cancellations of planned surgery due to insufficient bed capacity.

Methods

This was a planned analysis of data collected as part of the Second Sprint National Anaesthesia Project: EPIdemiology of Critical Care provision after Surgery (SNAP-2: EPICCS) study—a prospective observational study into perioperative risk and critical care provision for adult inpatient surgery.[15] We report our findings in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.[16] All hospitals in the UK undertaking adult surgery were approached to participate via their Quality Audit and Research Coordinator (QuARC): this is a network of anaesthetists managed by the Health Services Research Centre (HSRC) based at the Royal College of Anaesthetists.[17] All patients undergoing inpatient surgery (defined as a procedure requiring the care of an anaesthetist and requiring an overnight stay in hospital) during a 1 week period (March 21–27, 2017) were eligible for recruitment. Ethical approval was obtained from the Health Research Authority (South Central - Berkshire B REC, reference number: 16/SC/0349). Permission to collect patient identifiable data without consent was granted through Section 251 exemption from the Confidentiality Advisory Group for England and Wales (CAG reference: 16/CAG/0087), and the NHS Scotland Public Benefit and Privacy Panel for Health and Social Care (PBPP reference: 1617-0126). Individual Health and Social Care Trust research and development department approvals were obtained for sites in Northern Ireland.

Patient characteristics and perioperative variables were collected prospectively by local clinicians providing clinical care (see Supplementary Material, Case Record Form). Only patients undergoing planned surgery were included in this analysis: we defined this as cases classified as elective or expedited according to the criteria established by the National Confidential Enquiry into Patient Outcome and Death (NCEPOD).[18] Clinicians recorded whether these patients had experienced a previous cancellation for the same surgical procedure, and the reason for this earlier cancellation, categorised as follows: insufficient bed capacity; clinical reasons; reasons not known; or other reasons which were reported as free-text. Free text responses were classified into the following categories: administrative error, patient did not attend, equipment problem, personal reasons (e.g. patient no longer wishing to undergo surgery), staff unavailable, and insufficient theatre capacity. The primary outcome was previous cancellation of the same operation due to inadequate bed capacity ('historical cancellations'). Each hospital additionally reported the number and reasons for day-of-surgery cancellations for each day of the recruitment period ('contemporaneous cancellations'), and described structural characteristics in an organisational survey.[19]

Statistical analysis

We report the incidence of historical cancellations in patients who proceeded to surgery during the period and incidence of contemporaneous cancellations during the study. We also report the reasons for both types of cancellations. Descriptive statistics for normally distributed continuous data are reported as mean (standard deviation, SD), and for non-normally distributed data as median (inter-quartile range). Continuous data were assessed for normal distribution using histogram plots and the two-sided Kolmogorov–Smirnov test. A P-value <0.05 was considered statistically significant.

Multilevel regression modelling of historical cancellations

We modelled reported previous cancellations due to insufficient bed capacity in a two-level (patients nested within

hospitals) multivariable logistic regression model with random intercepts for hospitals. Multilevel regression modelling considers the fact that cancellations may cluster within hospitals during the study period and therefore may have correlated errors.[20,21] The random intercept introduced in our model allows for cancellations to be more frequent in one hospital than another, and reduces bias in the estimates of other model coefficients. We performed a complete cases analysis (excluding cases with missing data) as we considered the proportion of cases with missing values to be negligible (1.0% of total cases).[22] The predictor variables were chosen *a priori* based on clinical plausibility and face validity for influencing cancellations, and to adjust for potential differences caused by case mix. Hospital-level continuous variables (hospital bed numbers, critical care bed capacity, general surgical bed capacity) were standardised by subtracting the mean and dividing by SD before entering the model. Patient-level variables included: age (categorised into three groups: 18–64, 65–79, and ≥80 yr)[23]; ASA Physical Status (1 or 2, 3, and 4 or 5)[23,24]; urgency of operation (NCEPOD-Expedited *vs* NCEPOD-Elective); operative severity (Minor, Intermediate, Major, Xmajor and Complex, as defined by AXA-PPP procedure codes)[23,25]; surgical specialty (categorised into eight groups, see Supplementary Material); whether the patient was admitted to hospital before surgery, whether the surgery was as part of a cancer pathway, and whether postoperative critical care admission was required.

Hospital-level variables included: hospital size (total number of hospital beds); critical care bed capacity (the proportion of critical care beds within total hospital beds); general surgical bed capacity (the proportion of general surgical ward beds within total hospital beds); presence of an emergency department; provision of tertiary services (any one from a list of 16 tertiary services; see Supplementary Material); and provision of enhanced care ward beds. Critical care beds were defined as Level 2 or Level 3 beds according to Intensive Care Society and Faculty of Intensive Care Medicine definitions.[26,27] Enhanced care ward beds were defined as areas within the hospital with bed capacity to provide any subset of critical care interventions outside of the traditional ICU or high-dependency unit (HDU).[19,28]

Model performance was assessed by computing the area under the receiver operating characteristic curve (AUROC), which can take values between 0.5 and 1.0, where <0.7 identifies a model with poor performance, 0.7–0.8 indicates acceptable performance, 0.8–0.9 indicates good performance, and >0.9 indicates high performance. We report the estimated odds ratios (OR) and Wald 95% confidence intervals (CI) of these ORs and associated *P*-values of the fixed-effects components for our final mixed-effects model.

Contemporaneous day-of-surgery cancellations

In addition to the historical cancellations data reported by individual patients, we also collected the number of day-of-surgery cancellations due to insufficient bed capacity for each day of patient recruitment reported at each hospital. These aggregated contemporaneous data were collected to estimate the incidence of cancellations during the 1 week of patient data collection. We used these aggregated data to perform a sensitivity analysis to confirm that the hospital-level associations detected in our multilevel logistic regression model were similar to those estimates in the patient-level data on previous cancellations. This was performed using a zero-inflated Poisson regression model in which the response variable (cancellations per day) was regressed against the same hospital-level variables as in our earlier model, with additional variables for day-of-week (see Supplementary Material for the full model).

Analyses were performed using the R Statistical Computing language (R version 3.4.2; R Foundation for Statistical Computing, Vienna, Austria), with the following packages enabled: tidyverse, lme4, sjPlot, tableone, pscl. Multilevel logistic regression models were constructed using the glmer command; zero-inflated Poisson models were constructed using the zeroinfl command. Codes for all analyses are available on request.

Results

Hospital and patient characteristics

Of 263 hospitals across the UK invited to participate in the SNAP-2: EPICCS study, 245 hospitals submitted patient data (response rate=93.2%). These hospitals operated within 156 English NHS Trusts, Scottish and Welsh NHS Health Boards, and Northern Irish Health and Social Care Trusts. This study therefore reports data from 90.2% of UK secondary care organisations offering adult surgical services. During the 1 week recruitment window, data were collected on 14 936 patients who underwent elective or expedited inpatient surgery, and complete data for analysis were available for 14 796 cases (Fig. 1).

There were 1499 patients (10.0%) who had their surgery cancelled at least once for the same procedure. Patients previously cancelled because of insufficient bed capacity were older, had higher ASA physical status, were more likely to be undergoing Xmajor or complex surgery, and were more likely to require postoperative critical care (Table 1). The most common single cause of previous cancellation was for clinical reasons (33.3%); however, insufficient bed capacity (31.0%) was almost as common, and together with insufficient operating

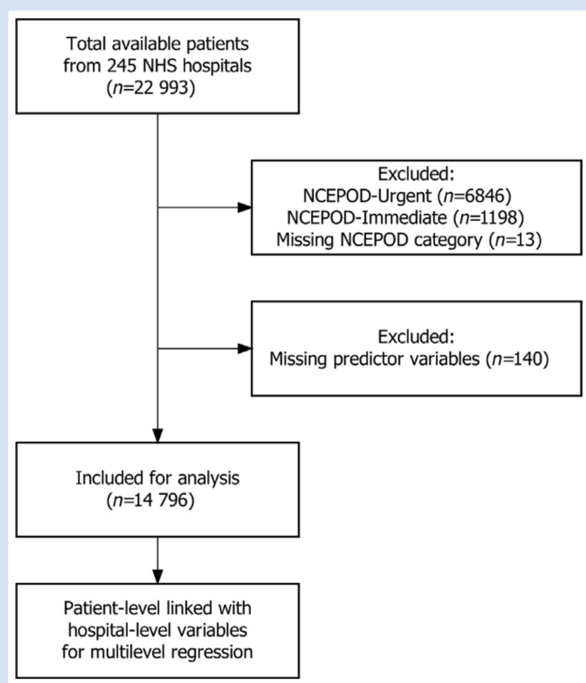

Fig 1. STROBE flow diagram of patients included and excluded from analysis.

Table 1 Patient characteristics. IQR, inter-quartile range; NCEPOD, National Confidential Enquiry into Patient Outcome and Death

	Previously cancelled because of insufficient number of beds		Overall
	No	Yes	
n	14 333	463	14 796
Age (median [IQR])	60 [42–72]	64 [50–74]	60 [43–72]
Sex = Male (%)	5875 (41.0)	202 (43.6)	6077 (41.1)
ASA physical status (%)			
1 or 2	10 452 (72.9)	318 (68.7)	10 770 (72.8)
3	3567 (24.9)	132 (28.5)	3699 (25.0)
4 or 5	314 (2.2)	13 (2.8)	327 (2.2)
NCEPOD-Expedited (%)	2835 (19.8)	40 (8.6)	2875 (19.4)
Patient admitted before surgery (%)	2786 (19.4)	60 (13.0)	2846 (19.2)
Operative severity (%)			
Minor	690 (4.8)	16 (3.5)	706 (4.8)
Intermediate	2311 (16.1)	49 (10.6)	2360 (16.0)
Major	5544 (38.7)	155 (33.5)	5699 (38.5)
Xmajor	3582 (25.0)	137 (29.6)	3719 (25.1)
Complex	2206 (15.4)	106 (22.9)	2312 (15.6)
Specialty (%)			
Gastrointestinal surgery	2211 (15.4)	84 (18.1)	2295 (15.5)
Gynaecology/urology surgery	2126 (14.8)	55 (11.9)	2181 (14.7)
Neuro/spinal surgery	3022 (21.1)	90 (19.4)	3112 (21.0)
Obstetrics	1534 (10.6)	11 (2.4)	1548 (10.4)
Orthopaedic surgery	3806 (26.4)	139 (30.0)	3946 (26.5)
Thoracic/cardiac surgery	622 (4.3)	46 (9.9)	668 (4.5)
Vascular surgery	348 (2.4)	13 (2.8)	361 (2.4)
Other specialty	2148 (14.9)	55 (11.9)	2203 (14.8)
Required postoperative critical care (%)	1532 (10.6)	105 (22.6)	1637 (11.0)
Cancer surgery (%)	2535 (17.5)	38 (8.2)	2575 (17.2)

theatre capacity (12.7%) and other potentially avoidable non-clinical reasons accounted for ~50% of cancellations (Table 2).

Multilevel logistic regression modelling of historical cancellations

Our multilevel logistic regression model (Table 3) exhibited good discrimination (AUROC=0.82; 95% CI, 0.81–0.84). The only patient-level predictor (Fig. 2) identified in our model that increased likelihood of cancellation was requirement for postoperative critical care (OR=2.92; 95% CI, 2.12–4.02; *P*<0.001).

In contrast, surgery for treatment of cancer (OR=0.32; 95% CI, 0.22–0.46; *P*<0.001), obstetric procedures (OR=0.17; 95% CI, 0.08–0.32; *P*<0.001), and NCEPOD-Expedited surgery (OR=0.39; 95% CI, 0.27–0.56; *P*<0.001) were associated with reduced odds of previous cancellation.

Hospital-level predictors (Fig. 3) associated with cancellation were presence of emergency department (OR=4.18; 95% CI, 2.22–7.89; *P*<0.001) and presence of enhanced care ward areas (OR=1.62; 95% CI, 1.13–2.33; P=0.009).

Contemporaneous day-of-surgery cancellations

During our 1 week study period, a total of 3724 cases were cancelled or rescheduled on the day of surgery, and 22 993 operations proceeded ahead. We therefore estimate that 13.9% of cases that week were cancelled on the day of surgery. Of these contemporaneous cancellations, 377 cases (10.1%) were cancelled due to insufficient bed capacity and 1029 cases (27.6%) for clinical reasons. In the remaining 2110 cases (56.7%), no reason for cancellation was specified. A sensitivity analysis conducted via zero-inflated Poisson regression using these contemporaneous data confirmed the hospital-level associations identified in the multilevel logistic regression model (see Supplementary Material).

Discussion

Principal findings

In this national 1 week study of NHS hospitals in the UK, 10% of patients attending hospital for planned inpatient surgery had previously experienced at least one cancellation for the same procedure. Multilevel logistic regression modelling demonstrated the association between treatment in a hospital with an emergency department and increased risk of cancellation. Patient-level risk factors for cancellation included the need for a postoperative critical care bed; however, cancer surgery, expedited surgery, and obstetric procedures were less likely to be cancelled. A large proportion of previous cancellations were attributed to non-clinical factors such as capacity or other hospital factors, and ~30% were attributable to clinical reasons.

Study strengths and limitations

To our knowledge, this represents the most comprehensive study of UK data for rates and reasons for surgical cancellations to date, with data from more than 90% of UK secondary care organisations offering adult surgical services. Our findings are therefore likely to be generalisable across the NHS and immediately relevant to healthcare policymakers, but specific

Table 2 Reasons for previous cancellations

Reported reasons	Count (*n*)	%
Clinical reasons	499	33.3
Non-clinical reasons		
Lack of beds	465	31.0
Insufficient operating theatre capacity	190	12.7
Personal reasons	36	2.4
Equipment problem	34	2.3
Staff unavailable	33	2.2
Administrative error	24	1.6
Patient did not attend	7	0.5
Not known	211	14.1
Total	1499	100

details might have limited generalisability outside of the UK. Previous research on this topic has been limited to single-centre reports,[7–13] with estimates of the incidence of cancellations varying widely, ranging from 0.15% to 39.0% of planned surgical cases.[8,12] Acknowledged difficulties with defining the denominator of how many operations are performed in the UK[29] means that it is difficult to estimate the proportion of operations that are cancelled using administrative data. NHS England publishes time-series statistics of elective surgery cancellations for non-clinical reasons, including the absolute number of cancellations and these numbers as a percentage of the number of total hospital admissions each quarter.[30] Our data correlate well with the number of cancellations recorded by NHS England during the same period in 2017 while additionally recording all causes of cancellations, not just non-clinical. Therefore, the comprehensiveness of our sample, along with the provision of denominator data, provides for the first time, robust national data that can be used to generate and test hypotheses to address the issue of surgical cancellations.

Limitations of this study include its 7 day cohort design, as the rates and reasons for cancellations in a week in March might not represent those occurring throughout the year. It is well-known that surgical cancellations follow a seasonal variation, with substantially higher cancellations occurring during the winter months.[14] Time-series methods of analysing cancellations have previously been suggested for tracking and monitoring variation in cancellation within individual institutions over time for the purpose of measuring hospital-level service quality.[31] Ideally, we would have liked to collect data over a longer duration in order to model cancellations over time, but achieving the quality and

Table 3 Multilevel logistic regression model

	Previously cancelled due to insufficient bed capacity		
	Odds ratio	95% CI	P-value
Patient-level fixed effects			
Age (yr)			
18–64	Reference		
65–79	1.01	0.81–1.26	0.946
≥80	1.13	0.81–1.57	0.474
ASA physical status			
ASA 1 or 2	Reference		
ASA 3	0.85	0.67–1.09	0.204
ASA 4 or 5	0.88	0.47–1.66	0.694
NCEPOD-Expedited surgery	0.39	0.27–0.56	<0.001
Patient admitted before surgery	0.77	0.56–1.06	0.110
Operative Severity			
Minor	Reference		
Intermediate	0.70	0.39–1.27	0.239
Major	1.05	0.61–1.82	0.863
Xmajor	1.03	0.58–1.83	0.920
Complex	0.95	0.52–1.73	0.863
Specialty			
Gastrointestinal surgery	Reference		
Gynaecology/urology	0.89	0.64–1.25	0.508
Neuro/spinal	0.97	0.58–1.61	0.897
Obstetrics	0.16	0.08–0.32	<0.001
Orthopaedics	1.09	0.79–1.49	0.599
Thoracic/cardiac	1.51	0.92–2.49	0.102
Vascular	0.86	0.45–1.66	0.657
Other surgery	0.91	0.63–1.32	0.621
Cancer surgery	0.32	0.22–0.46	<0.001
Postoperative critical care planned	2.92	2.12–4.02	<0.001
Hospital-level fixed effects			
Hospital size	0.98	0.80–1.20	0.843
Proportion of critical care beds	1.07	0.88–1.30	0.485
Proportion of general surgical beds	0.88	0.72–1.08	0.234
Tertiary services offered	1.08	0.72–1.62	0.696
Emergency department present	4.18	2.22–7.89	<0.001
Enhanced care wards present	1.62	1.13–2.33	0.009

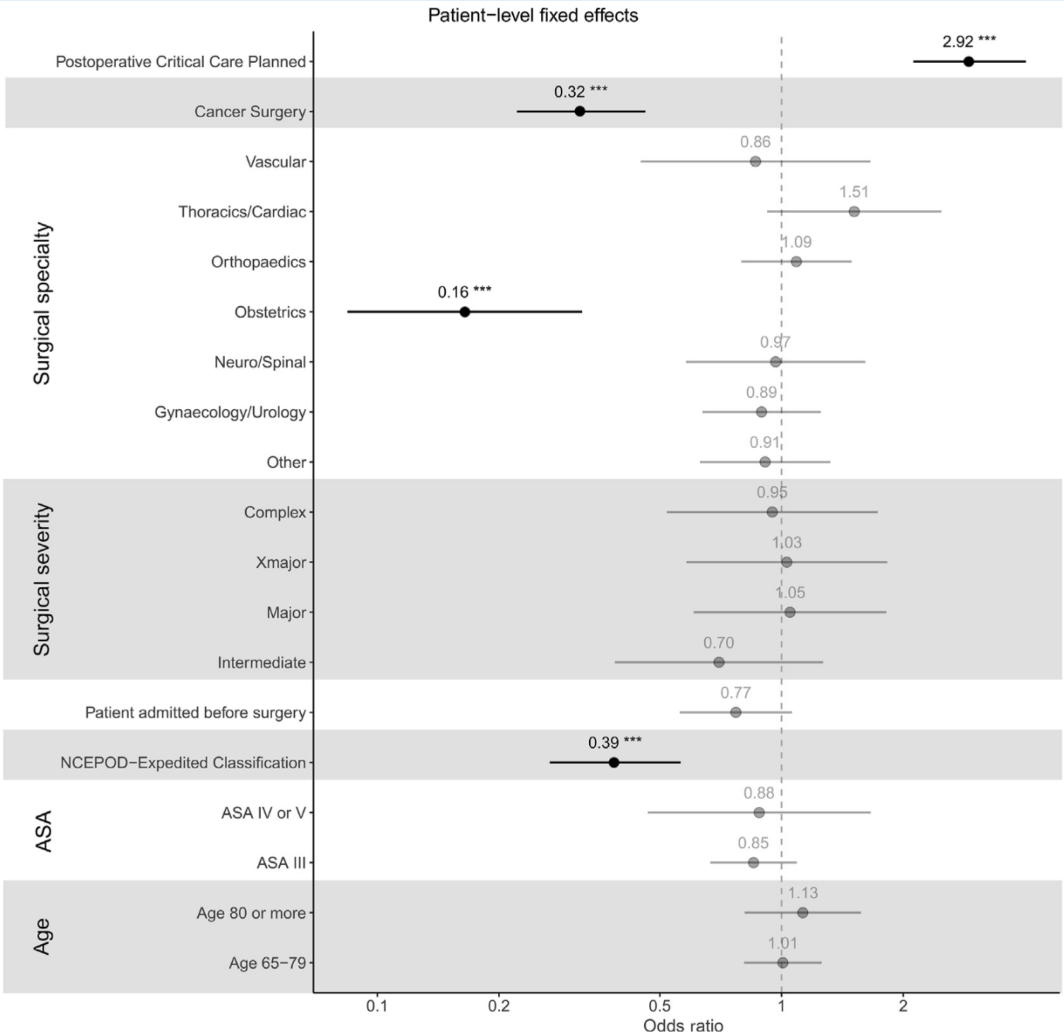

Fig 2. Patient-level fixed effects associated with the likelihood of experiencing a previous cancellation. Significant effects are highlighted in black, and insignificant effects have been de-emphasised for clarity of interpretation. * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.

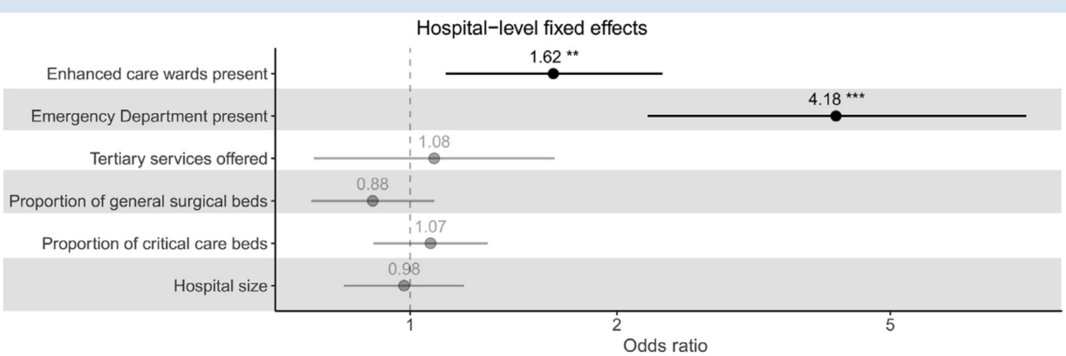

Fig 3. Hospital-level fixed effects associated with the likelihood of experiencing a previous cancellation. Significant effects are highlighted in black, and insignificant effects have been de-emphasised for clarity of interpretation. * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.

granularity of data we wanted over a longer period is unlikely to have been feasible across the 245 hospitals in our study.

We also could not distinguish between clinical cancellations due to inadequate preoperative preparation (e.g. failure to stop anticoagulants or poor patient optimisation), or unpreventable acute illness (e.g. respiratory tract infection). Finally, as we modelled historical cancellations in patients who eventually underwent surgery, we might not have captured patients who had planned surgery cancelled but then subsequently presented for emergency surgery or died; thus, we might have underestimated both the incidence and impact of cancellations. Future studies or audits of avoidable cancellations should consider these issues in design.

Clinical implications

Our study highlights that a substantial proportion of patients who undergo inpatient surgery are cancelled at least once, representing both an opportunity cost to the NHS, and distress and potential harm to patients.[1–3] Cancellations prolong surgical waiting lists, and can represent inefficient use of resources.[8] Prolonged patient suffering, worsened patient experience, and delays resulting in worsened clinical outcomes have all been reported consequences to cancellations.[1–3] Furthermore, patients affected by cancellations may experience negative psychological impacts on levels of anxiety and mood, and suffer personal economic hardship from repeatedly planning time away from work.

Our findings suggest that clinicians prioritise cases appropriately when clinical resources are limited. However, it is of interest that patients treated in hospitals with enhanced care wards are more likely to be cancelled. We propose that hospitals with insufficient critical care capacity to meet demand have attempted to mitigate against cancellations or poor quality care through development of enhanced ward facilities; however, these may not completely solve the capacity problem.

Our data can be used to guide developments in the structures of surgical services. For example, ring-fencing of beds for elective surgery is a recommendation from the Getting It Right First Time national review of orthopaedic and cardiothoracic surgery services in England, although it is not clear if this approach would generalise more widely.[32,33] Service redesign of this type is further supported by our finding that despite maternity units generally providing a high-volume service including both emergency and planned surgery, obstetric patients are much less likely to be cancelled; this is likely to be because most hospitals have dedicated wards and operating theatres for obstetric patients.[34,35] However, the challenges of implementing a ring-fenced solution in a hospital that also provides emergency care cannot be underestimated, as the effect of ring-fencing might impact on other hospital workflows. Other solutions to these issues include seasonal planning, where fewer planned procedures are scheduled for the winter months, and instead clinical capacity is diverted to emergency care and outpatient clinics. This is similar to the action taken by NHSE during January of 2018; however, earlier planning might support a reduced number of late cancellations. Similarly, increasing dedicated emergency surgical capacity in hospitals with emergency departments might allow for provision of emergency surgery without encroaching on capacity to undertake elective operations. This could be through provision of beds on dedicated emergency surgery units, greater emergency operating theatre capacity, or both. There is substantial evidence that avoiding delay in emergency cases is of patient benefit, and national guidelines now recommend prompt surgery in, for example, hip fractures and emergency laparotomies.[36–38]

Our study highlights an area of opportunity for improvement through structured auditing of cancellations data at local levels. Analysis of non-clinical reasons for cancellation according to a similar categorisation used in this study might enable hospitals to focus on specific areas where interventions can reduce the risk of cancellation. Although some hospital information technology systems already collect and encode such data routinely,[10,12] it is by no means ubiquitous. Furthermore, the quality of preoperative assessment and optimisation, and of communication between patients and hospitals before surgery could be more closely investigated to develop strategies to mitigate against late cancellation for clinical reasons.

Finally, our findings suggest that patients who are deemed by their clinicians to require postoperative critical care can have their procedures postponed in the event of critical care beds being unavailable. The UK has fewer critical care beds per capita than many other high- and middle-income countries,[39,40] and these findings suggest inadequate surgical critical care capacity in the UK. Lack of critical care capacity was the principal reason for cancellation of surgery in hospitals where unusually high levels of expedited cases were postponed.[41] Operational research that uses mathematical modelling to forecast patient flows and therefore reduce cancellations due to critical care bed shortages has had some success in mitigating these risks.[42,43]

However, the issue of which patients require critical care after surgery is not straightforward. Critical care support is used for specific interventions (e.g. ventilator or vasopressor support) or to facilitate enhanced monitoring and nursing surveillance at a time of high perioperative risk. Possibly because of the heterogeneity of the critical care 'intervention', guidelines recommending which patients require this resource are based predominantly on expert opinion rather than trial data; furthermore, different guidelines and specialties have different views on how patients should be prioritised for postoperative critical care admission.[44,45] For example, it is routine to send patients to critical care after elective cardiac surgery, but not necessarily after elective major bowel surgery, which has higher postoperative mortality and complication rates.[46,47]

Recent large-scale studies also raise the issue of whether critical care is of benefit to all patients, or whether in fact some may be harmed by inappropriate interventions.[48,49] Research is needed into which patients would benefit most from critical care so as to make best use of this limited resource. Although there are ethical and practical challenges around conducting randomised trials in this area,[46,48,50] novel statistical techniques designed for inferring causation in observational studies may provide a solution—to that end, the main analysis of the SNAP-2: EPICCS study will attempt to address this question.[15]

In conclusion, a large number of surgical cancellations occur within the UK, and in the majority of cases these are attributable to non-clinical reasons. Structural modifications, in particular around service reconfiguration to separate emergency and elective care, and seasonal planning, should be modelled and evaluated for clinical and cost effectiveness.

Authors' contributions

Study conception: S.R.M.
Ethics application: D.J.N.W., S.R.M.
Data collection: SNAP-2: EPICCS collaborators.
Data preparation: D.J.N.W.
Data analysis and interpretation: D.J.N.W., S.K.H., S.R.M.
All authors were involved in manuscript preparation, revisions, and final manuscript approval.
Chief Investigator and guarantor: S.R.M.

Acknowledgements

The authors thank the SNAP-2: EPICCS collaborators for all data collected (a full list of collaborators and their affiliations is included in the Supplementary Material). In particular, the authors thank T. Cook for providing comments and suggestions to the manuscript, our lay representative R. Shawyer for his invaluable input at all stages of the study, and the Quality Audit and Research Coordinator (QuARC) Network of the Health Services Research Centre at the Royal College of Anaesthetists for supporting the study at their hospitals. We thank the following Trainee Research Networks for helping to coordinate the study in their regions of the UK: Research & Audit Federation of Trainees (RAFT), Anaesthetic Audit and Research Matrix of Yorkshire (AARMY), Intensive Care & Anaesthesia Research Network of North East Trainees (INCARNNET), Merseyside Anaesthetic Group for Improving Quality (MAGIQ), North West Research and Audit Group (NWRAG), Oxford Critical Care Anaesthetic Research Enterprise (OxCCARE), Pan-London Peri-operative Audit & Research Network (PLAN), Scottish East Quality Improvement & Research Academy (SEQuoIA), SESSA Quality Improvement and Research Network (SQUARES), Severn Trainees Anaesthetic Research (STAR), South West Anaesthetic Research Matrix (SWARM), South Yorkshire Hospitals Audit and Research Collaboration (SHARC), Southcoast Peri-operative Audit and Research Collaboration (SPARC), Welsh Anaesthetic Audit Research & Engagement Network (WAAREN), West Midlands Trainee Research Anaesthesia & Intensive Care Network (WMTRAIN).

Declaration of interest

SRM is the associate national clinical director for elective care at NHS England.

Funding

SNAP-2: EPICCS was supported by the National Institute of Academic Anaesthesia (Association of Anaesthetists of Great Britain and Ireland Project grant): WKR0-2014-0061, the UCL/UCLH Surgical Outcomes Research Centre, the Royal College of Anaesthetists and the UCLH NIHR Biomedical Research Centre. The study is adopted in the UK onto the NIHR Clinical Research Portfolio and equivalents in the devolved nations, and supported by NIHR Local Clinical Research Networks. SRM and SKH are Improvement Science Fellows funded by the Health Foundation. SRM is supported for her role as Director of the NIAA Health Services Research Centre by funding from the Royal College of Anaesthetists. DJNW receives a clinical salary from The London Clinic hospital and a clinical research fellowship salary from the UCL/UCLH Surgical Outcomes Research Centre.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.bja.2018.07.002.

References

1. Tait AR, Voepel-Lewis T, Munro HM, Gutstein HB, Reynolds PI. Cancellation of pediatric outpatient surgery: economic and emotional implications for patients and their families. *J Clin Anesth* 1997; **9**: 213–9
2. Ivarsson B, Kimblad PO, Sjöberg T, Larsson S. Patient reactions to cancelled or postponed heart operations. *J Nurs Manag* 2002; **10**: 75–81
3. Magnusson H, Felländer-Tsai L, Hansson MG, Ryd L. Cancellations of elective surgery may cause an inferior postoperative course: the 'invisible hand' of health-care prioritization? *Clin Ethics* 2011; **6**: 27–31
4. Oliver D. Blaming hospitals for systemwide problems will make winter bleaker. *Br Med J* 2017; **359**: j4553
5. Pym H. *Operating theatres 'waste two hours a day'*. BBC News; 24 October 2017. https://www.bbc.co.uk/news/health-41727535
6. Lay K, Smyth C, Maguire P. *NHS chiefs defend cancellation of thousands of operations*. The Times; January 3 2018. https://www.thetimes.co.uk/article/nhs-chiefs-defend-cancellation-of-thousands-of-operations-r2jtf7vjz
7. Rai MR, Pandit JJ. Day of surgery cancellations after nurse-led pre-assessment in an elective surgical centre: the first 2 years. *Anaesthesia* 2003; **58**: 692–9
8. Lau H-K, Chen T-H, Liou C-M, Chou M-C, Hung W-T. Retrospective analysis of surgery postponed or cancelled in the operating room. *J Clin Anesth* 2010; **22**: 237–40
9. Kumar R, Gandhi R. Reasons for cancellation of operation on the day of intended surgery in a multidisciplinary 500 bedded hospital. *J Anaesthesiol Clin Pharmacol* 2012; **28**: 66–9
10. Dimitriadis PA, Iyer S, Evgeniou E. The challenge of cancellations on the day of surgery. *Int J Surg* 2013; **11**: 1126–30
11. Bass E, Gill P. Report into "on the day cancellations" for plastic surgery in patients who failed to stop their medication. *BMJ Open Qual* 2014; **3**. u204762.w2037
12. Caesar U, Karlsson J, Olsson L-E, Samuelsson K, Hansson-Olofsson E. Incidence and root causes of cancellations for elective orthopaedic procedures: a single center experience of 17,625 consecutive cases. *Patient Saf Surg* 2014; **8**: 24
13. Kaddoum R, Fadlallah R, Hitti E, EL-Jardali F, El Eid G. Causes of cancellations on the day of surgery at a Tertiary Teaching Hospital. *BMC Health Serv Res* 2016; **16**: 259
14. The Nuffield Trust. *Cancelled NHS operations. QualityWatch care quality indicators* 2017. http://www.qualitywatch.org.uk/indicator/cancelled-operations
15. Moonesinghe SR, Wong DJN, Farmer L, Shawyer R, Myles PS, Harris SK. SNAP-2 EPICCS: the second Sprint national anaesthesia Project of critical care after surgery: protocol for an international observational cohort study. *BMJ Open* 2017; **7**. e017690
16. Elm E von, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *Lancet* 2007; **370**: 1453–7
17. Walker EMK, Bell M, Cook TM, Grocott MPW, Moonesinghe SR, for the SNAP-1 investigator group. Patient reported outcome of adult perioperative anaesthesia

in the United Kingdom: a cross-sectional observational study. *Br J Anaesth* 2016; **117**: 758–66
18. NCEPOD. *Classification of intervention*. National Confidential Enquiry into Patient Outcome and Death (NCEPOD); 2004
19. Wong D, Bedford J, Chazapis M, et al. Postoperative critical care facilities in the UK: not as simple as 1-2-3. *Anaesthesia* 2018; **73**: 71
20. Gelman A, Hill J. *Data analysis using regression and multilevel/hierarchical models*. New York, USA: Cambridge University Press; 2007
21. Garson GD. *Hierarchical linear modeling: guide and applications*. London, UK: Sage; 2013
22. Graham JW. *Analysis of missing data*. New York, USA: Springer; 2012. p. 47–69
23. Protopapa KL, Simpson JC, Smith NCE, Moonesinghe SR. Development and validation of the Surgical Outcome Risk Tool (SORT). *Br J Surg* 2014; **101**: 1774–83
24. Cullen DJ, Apolone G, Greenfield S, Guadagnoli E, Cleary P. ASA Physical Status and age predict morbidity after three surgical procedures. *Ann Surg* 1994; **220**: 3–9
25. AXA PPP healthcare. *Specialist procedure codes* 2016. https://online.axappphealthcare.co.uk/SpecialistForms/SpecialistCode.mvc/Print?source=contracted
26. Intensive Care Society. *Levels of critical care for adult patients*. London, UK: Intensive Care Society; 2009
27. *Core standards for intensive care units*. Faculty of Intensive Care Medicine & Intensive Care Society; 2013
28. Batchelor A, Pittard A, Ripley A, Waeland D, Waldmann C. *Critical futures: a report on the first wave survey*. London, UK: The Faculty of Intensive Care Medicine; 2017
29. Abbott TEF, Fowler AJ, Dobbs TD, Harrison EM, Gillies MA, Pearse RM. Frequency of surgical treatment and related hospital procedures in the UK: a national ecological study using hospital episode statistics. *Br J Anaesth* 2017; **119**: 249–57
30. NHS England. *Cancelled elective operations* 2018. https://www.england.nhs.uk/statistics/statistical-work-areas/cancelled-elective-operations/
31. Dexter F, Marcon E, Epstein RH, Ledolter J. Validation of statistical methods to compare cancellation rates on the day of surgery. *Anesth Analg* 2005; **101**: 465–73
32. Briggs T. *Getting it Right First Time: a national review of adult elective orthopaedic services in England*. NHS Improvement (NHSI) Operational Productivity Directorate; 2015
33. Richens D. *Getting it Right first time: cardiothoracic surgery national specialty report*. NHS Improvement (NHSI) Operational Productivity Directorate; 2018
34. Royal College of Obstetricians and Gynaecologists, Royal College of Midwives, Royal College of Anaesthetists, Royal College of Paediatrics and Child Health. *Safer childbirth: minimum standards for the organisation and delivery of care in labour*. Royal College of Obstetricians and Gynaecologists; 2007
35. Department of Health. *Health building note 09-02: maternity care facilities*. UK: Department of Health; 2013
36. Wilkinson K, Martin IC, Gough MJ, et al. *An age old problem: a review of the care received by elderly patients undergoing surgery*. National Confidential Enquiry into Patient Outcome and Death (NCEPOD); 2010
37. NELA Project Team. *Third patient report of the national emergency laparotomy audit*. London: Royal College of Anaesthetists; 2017
38. Royal College of Physicians. *National hip fracture database annual report 2017*. London): Royal College of Physicians; 2017
39. Adhikari NK, Fowler RA, Bhagwanjee S, Rubenfeld GD. Critical care and the global burden of critical illness in adults. *Lancet* 2010; **376**: 1339–46
40. Rhodes A, Ferdinande P, Flaatten H, Guidet B, Metnitz PG, Moreno RP. The variability of critical care bed numbers in Europe. *Intensive Care Med* 2012; **38**: 1647–53
41. Campbell D. *Hospitals cancelling urgent surgery despite NHS bosses' orders*. The Guardian; Sun 4 Feb 2018. https://www.theguardian.com/society/2018/feb/04/hospitals-cancelling-urgent-surgery-despite-nhs-bosses-orders-england-cancer-heart-operations
42. Pearson GA, Reynolds F, Stickley J. Calculating the need for intensive care beds. *Arch Dis Child* 2012; **97**: 943–6
43. Utley M, Peters M. Bring on the geeks: the case for improved modelling of capacity requirements. *Arch Dis Child* 2012; **97**: 933–4
44. Findlay GP, Goodwin APL, Protopapa K, Smith NCE, Mason M. *Knowing the risk: a review of the peri-operative care of surgical patients*. National Confidential Enquiry into Patient Outcome and Death (NCEPOD); 2011
45. Anderson I, Eddleston J, Grocott M, et al. *The higher risk general surgical patient: towards improved care for a forgotten group*. London: The Royal College of Surgeons of England; Department of Health; 2011
46. Pearse RM, Harrison DA, James P, et al. Identification and characterisation of the high-risk surgical population in the United Kingdom. *Crit Care* 2006; **10**: R81
47. Smith D. *Guidance on the provision of cardiac and thoracic Anaesthesia services 2016 (chapter 18). Guidelines for the Provision of Anaesthesia Services (GPAS)*. London: Royal College of Anaesthetists; 2016
48. Kahan BC, Koulenti D, Arvaniti K, et al. Critical care admission following elective surgery was not associated with survival benefit: prospective analysis of data from 27 countries. *Intensive Care Med* 2017; **43**: 971–9
49. Taccone P, Langer T, Grasselli G. Do we really need postoperative ICU management after elective surgery? No, not any more! *Intensive Care Med* 2017; **43**: 1037–8
50. Sobol JB, Wunsch H. Triage of high-risk surgical patients for intensive care. *Crit Care* 2011; **15**: 217

Handling editor: H.C. Hemmings Jr