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Describing the high-risk surgical population: A national epidemiological study in England, Scotland, and Wales.

SAP::

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Introduction

More than 5 million surgical procedures are performed in the National Health Service each year, with 49,000 deaths within 30 days.[1] Providing surgical care accounts for over £9.5billion each year (8% of the NHS budget) and yet we know worryingly little about the patients who undergo surgery. Some specialities, like cardiac surgery, collect detailed data on their patients but these audits leave most patients unaccounted for.[2,3]

A sub-group of around 250,000 patients have previously been described that are concealed within the large surgical population, but account for four out of five deaths after surgery.[4] These patients are thought to be at increased risk because of co-morbid disease, advanced age and the magnitude of the required surgery. However, the study identifying this patient group was performed over 10 years ago, used in-hospital mortality, and considered procedure related risk only. Important features, like chronic diseases, deprivation and ethnicity were not considered and limit the utility of this model. Long-term outcomes are related to the underlying disease requiring treatment, the surgical procedure performed and patient specific risks factors. While unpicking these features is challenging, existing measures of short-term harm may be an important measure of harm, but do not reflect success for patients. Understanding long-term outcomes of high-risk groups is vital to inform national healthcare planning, and patients of their future outlook.

At present, long-term survival and healthcare need following surgical procedures performed in the NHS is unknown. The aim of this study is to provide a robust description of the high-risk surgical population, including the size and characteristics of these groups at an epidemiological level in the UK. We do not seek to provide patient level estimates of postoperative risk of death.

Aims

1. To develop a risk-model of 1-year mortality after surgery.
2. To risk stratify the surgical population based on the risk of one year death after surgery, using data from England.
3. To quantify the size of the high-risk surgical population in England, Scotland and Wales using the approach from aim 1.
4. To demonstrate how the size of the high-risk population has changed over time and model potential future scenarios.
5. To determine the Intensive care requirements of patients in different risk groups, using linked data in Scotland.

Methods

This will be a study using routinely collected data, linked to other sources as outlined below. The study will be conducted and reported in line with the Transparent Report of multivariable prediction model for individual prognosis or diagnosis (TRIPOD) statement.[5]

Data sources

1. Hospital Episode Statistics, NHS England (2010-2016)
2. Office for national statistics death registry data (2010-2018)
3. SMR linked to SICSAG & Scottish mortality data in Scotland (2010-2016)
4. PEDW linked to A&E, OP, ONS/Welsh Death Service mortality data in Wales (2010-2016)

Core development of the modelling approach will be performed in England, the model will be applied in Wales and Scotland to provide a nationwide overview of the high-risk surgical population.

Inclusion criteria

Adult patients who meet a prior definition based on Office of Population Censuses and Surveys intervention and procedure codes (OPCS version 4.7) will be included ('core procedure definition').[1,6] The core procedure definition will identify procedures typically performed in an operating theatre, or requiring general/regional anaesthesia. We anticipate this will identify 25 million eligible patient episodes in England over the five-year study period. Nested within this definition is a group of major surgical ('major procedure definition') that we will use to select the most major procedure someone undergoes if patients have multiple procedures on one day. Obstetric procedures (identified by relevant OPCS codes) or maternity admissions (identified by relevant admission method codes) will be excluded, as will organ retrieval operations (identified by OPCS version 4.7: X45.X, X46.X).[7]

Index surgical procedure

The index surgical procedure will be the first meeting the definition of surgery as defined above. Where multiple operations are performed on the same day we will consider the most 'major' procedure as index procedure, defined by presence in the major surgical definition followed by codes present in the core procedure definition. If multiple procedures are present from the either definition, we will select the highest ranked major procedure by operation sequence.

Cohort construction

Patients may require multiple procedures over the course of the study period. To maximise use of data and to ensure risk over time is adequately captured, patients will be able to enter the study cohort more than once. Each patient will enter on the date of their first operation, which will start a 365-day surgical window. After 365 days, patients will re-enter the cohort if they have a subsequent surgical procedure. Where patients have multiple operations during a 365-day period, we will present the count of these. The first procedure during each window will be the index surgical procedure. This will generate a sequence of 'surgical episodes' and each will have an associated 'survived' or 'died' flag attached. 'Died' will be assigned to individuals who die within 365 days of their surgery. This will form the outcome measure for model development.

Principal variables

Age will be that recorded at the start of the index surgical episode in completed years. Sex will be that recorded at the start of the index surgical episode. Ethnicity will be handled as five categories based on the ethnicity code recorded nearest the time of surgery. Deprivation will be recorded as quintile based on the index of multiple deprivation (2019) rank of each individual's residential lower super output area.[8] Chronic disease will be captured using the Charlson comorbidity index using the Royal College of Surgeons Score definition for each disease.[9] The indication for surgery will be the primary ICD-10 code, mapped to Clinical Classifications Software Refined categories (this will not be included in the model).[10] A restricted, two-year look back file will be used to identify diseases from all episodes associated with any patient before surgery and include the index surgical episode. We will test using two administrative data-based frailty measures: the Secondary Care Administrative Records Frailty (SCARF index)[11] which improves the discrimination of survivors in models of elderly surgical patients, and the hospital frailty risk score (HFRS)[12] which has moderate agreement with the Rockwood frailty index. We will determine which to use in the model based on improvement in pseudo-R^2 in an age and sex adjusted model when these variables are included.

The definition of surgery includes ~1700 OPCS 4 codes including these individually is computationally infeasible and will be uninterpretable if it were to work. We have previously described a mapping of these to 18 categories, based on the anatomical location associated with the procedure.[13] However, these overlook important within-category differences, for example vascular surgery may include abdominal aortic aneurysm repair and varicose vein surgery which represent very different clinical scenarios. To account for this difference, we will include a measure of short-term harm associated with each procedure. This will be the age-standardised rate of 30-day death, calculated for each threecharacter OPCS 4.7 code. Age-standardisation will be performed by adjusting for the population age structure of England, derived from Office for National Statistics population data. This approach will allow adjustment for the immediate risk of death after surgery, and considers both disease and procedure related risk of early death. Including this variable is reasonable because the aggregated risk of early death for most procedures is readily available for clinicians and policy makers.

We will explore modelling this as both a continuous variable (including non-linear associations), and as a categorial variable divided into the following, pre-specified groups:

1. Very low risk (<0.5%)
2. Low risk (0.5-1%)
3. Moderate risk (1-2.5%)
4. High risk (2.5-5%)
5. Very high risk (>5%)

The type of admission will be classified as either emergency or elective based on admission method codes. The year of surgical procedure will be used to account for temporal changes in outcomes over the study period.

Outcome measure

Death within 365 days of surgery, captured using linkage to office for national statistics civil registration records in England, Welsh Demographic Service Dataset and National Records Scotland.

Statistical analysis steps

All analyses will be completed using R (version 4.1.0, R Core Team) and associated packages. The following steps will be undertaken. We will present each of variables in the principal variables section with their frequency and associated risk of one year death. Age (a continuous variable) will be presented in ten-year bands. Statistical analysis steps are outlined in figure 2.

We will use a multivariable logistic regression model to derive a modelled probability of death for each patient. The logistic regression model will have a dependent variable of death within 365 days of surgery, and the variables listed in principal variables as independent variables. These variables have been selected based on biological plausibility. Age will be treated as a continuous variable. We will explore potentially non-linear associations using polynomial terms. If a failure of the model to converge occurs because of certain feature combinations not being present within the data, we will combine groups based on expert clinician input.

We will assign each patient in the dataset a probability of death. We will identify a cut off value of high-risk where 80% of deaths within one year are captured (i.e. a sensitivity of 80%). We will also divide the cohort into deciles of risk and present the number of patients. We will test a range of cut offs and aim to identify where we have maximised enrichment using the Youden index.

We will present:

a) The characteristics of high-risk and non-high-risk patients including, age, sex, IMD, ethnicity, surgical procedure group, frequency of chronic diseases and the index ICD-10 code, mapped to CCSR categories (top 10 presented with >0.5% prevalence)[10].
b) We will present the 10 commonest performed procedures, with the number and proportion of patients at high-risk and the rate of death among high risk and non high-risk patients.
c) We will present the number of procedures and rate of death associated with some exemplar procedures, divided by high-risk or non-high-risk patients. (Aortic surgery, large intestine procedures, abdominal procedures, hip/knee revisions, neck of femur fracture, stomach or duodenal procedures, oesophagus procedures, lower limb arterial surgery, open kidney procedure, primary hip replacement, transurethral resection of prostate, cataract removal, appendicectomy). These procedures were selected in a prior paper presenting high-risk surgical patients.[4]
d) The overall number of cases, and deaths within one year after surgery among high-risk and non-high-risk patients.
e) Survival curves out to five years after surgery.
f) We will present the proportion of patients considered high-risk divided into nine regions as a heat map:
    a. Scotland/Wales/South west/South east/Midlands/London/East of England/North west/North east & Yorkshire.
g) We will additionally present the proportion of high-risk patients, divided by index of multiple deprivation deciles. We will consider combining c) and d) to demonstrate how deprivation and geographical location interact.

Sensitivity analyses

The number of variables to be included in the model is deliberately limited and as such the core model will not include any variable selection steps. We will test if variable selection improves the model quality, by using a backward step procedure informed by improving Akaike information criterion (AIC).

The RCS Charlson score includes important long-term diseases that influence patient outcome. To explore if the addition of other long-term diseases improves the model, we will add additional diseases captured by the Elixhauser comorbidity index that are not in RCS Charlson (Cardiac arrhythmia, Arterial hypertension, Arterial hypertension with complications, Other neurological disease, pulmonary vascular disease, Lymphoma, coagulopathies, obesity, weight loss, electrolyte disorders, iron-deficiency anaemia, alcohol abuse, drug abuse, psychosis, depression, anaemia due to bleeding). Elixhauser diseases will be identified by using ICD-10 codes from a lookback file and the index surgical episode.[14] These will be included as binary variables and will be added to the core model alongside the Charlson comorbidity index domains.

To determine which of the core or sensitivity analysis models performs best, we will determine the calibration and discrimination of each. Calibration will be assessed by presenting the observed mortality in deciles of forecasted risk and the global goodness of fit test. Discrimination will be measured using the C-statistic (or area under the receiver-operator characteristic curve), confidence intervals will be derived by a non-parametric bootstrap resampling procedure.[15] It will also be externally measured in Wales & Scotland, which represents a ‘hold out’ set of data where the model can be applied after training to externally measure calibration and discrimination.

To explore how the size of the high-risk population has changed, we will do a sensitivity analysis by summarising the proportion of patients at high-risk and their associated risk of death over each year of the study.

Intensive care utilisation

In Scotland, we will use linked data describing intensive care use following surgery. We will present the number of days spent in Intensive care, divided to planned and unplanned admissions, within one year of surgery.

Secondary analysis

To estimate how the size of the high-risk population will change in the future. We will determine the characteristics associated with high-risk patients, which we anticipate will include advanced age and a higher burden of chronic disease.

We will estimate how the high-risk population will change over the next decade. The core model will be based on age and procedure volume changes. We will use prior estimates of changes in the population age, age of the surgical population and number of procedures performed for different age groups to do this.[16,17] We will supplement this with projections of chronic disease accumulation in developed nations to provide further refinement.[18 19]

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Appendix A. Required data points

Field	Field Name (format)	Reason	Variable type (Reg)
COHORT IDENTIFICATION			
STARTAGE	Age on admission (3n)	Age	cont
ADMIDATE	Admission date (dd/mm/yyyy)	Temporal trends	cont
ADMIFLAG	Confirm admission to hospital (Y = Yes, N = No)	Double check episode = admission	N/A
OPERTN_3_CONCAT	3 Character concatenated procedure code (OPCS 3 char)	For case selection	N/A
SPELL INFORMATION			
ADMIMETH	Method of admission (2n) (Elective: 11, 12, 13. Emergency: 21,22,23,24,2A, 2B,2C,2D. Mental Health: 25. 'Other Means' : 28)	Confirm if emergency/elective admission to hospital	Cat
CLASSPAT	Patient Classification (1n) (1=ordinary, 2=Day case, 3=regular day, 4=regular night, 5=mothers at delivery, 8=N/A (maternity event), 9 = unknown)	Identify day case vs. IP care	cat
EPIDUR	Episode duration (5n)	To enable spell construction	cont
EPIKEY	Record identifier	?required to construct spells	n/a
EPIORDER	Episode Order	To determine the number of episodes within current spell.	n/a
CHAPTER	ICD-10 primary diagnosis chapter	Primary diagnosis chapter for ICD-10 code	n/a
FAE_EMERGENCY	Finished admission episode, emergency classification (1n) (1 = Emergency, 0 = all other episodes)	For crosscheck emergency admission	Cat
OPERSTAT	Operation status code (1n) (1 = procedure carried out, 8 = no operative procedures performed/intended, 9 = no data entered)	To remove those without operative procedure performed.	n/a

INTMANIG	Intended management (1n)	For comparison with CLASSPAT (which is what the actual management was).	n/a
PATIENT INFORMATION			
HESID	Patient identifier (10n)	For mapping subsequent use.	n/a
SEX	Sex of patient (1n)(1=Male, 2=Female, 3=Indeterminate, 9=not specified, 0=not known)	3 only before 1996. For sex in models/characteristics.	Cat
DIAG_3_CONCAT	3 Char concatenated diagnosis (79n, ICD-10)	For all diagnoses	Cat
DIAG_3_NN	Diagnosis – 3 chars (3n)	Each diagnosis	Cat
DIAG_4_CONCAT	4 Char concatenated diagnosis (99n, ICD-10)	Detailed diagnoses all	Cat
DIAG_4_NN	Diagnosis 4 chars (4n)	Each diagnosis	Cat
DIAG_COUNT	Count of diagnoses (2n)	Number of diagnoses.	n/a
DIAG_NN	All diagnosis codes (6n, ICD10)	25 fields for all diagnoses	
OPDATE_NN	Date of operation (dd/mm/yyyy) x 24	Op date needed for year of op & motility F/U	n/a
DOMPROC	Trust derived dominant procedure	Interesting to see difference between dominant procedure and main code listed?	LEVEL 2
OPRTN_3_N	3 Character for main code (3n, OPCS)	?difference CONCAT/N	LEVEL 2
OPERTN_4_CONCAT	4 Character concatenated proc code (OPCS 4char)	As above	LEVEL 2
OPERTN_4_NN	All procedure codes (24 x 4n)	?OPER_01 = most resource intensive procedure and therefore main.	
IMD04_DECILE	IMD Decile Group (20an, code)	IMD as a forecast for outcome to complement QOL work	Ordinal
MAINSPEF	Main specialty (3n)	Define specialty	LEVEL
TRETSPEC	Treatment Specialty (3n, code)	Specialty of consultant working, rather than contracted.	
HRG_N.N	Healthcare resource group: v3.1	Applied HRG for cost estimation	Na
MATCHID	Patient identifier matcher	?required for supraspelling	
PREOPDUR	Preoperative duration (3n)(days)	Preoperative time in hospital	
OUTCOMES			

POSOPDUR	Postoperative duration (3n)(days)	Postoperative time in hospital	OUTCOME
SUSHRG	SUS generated HRG	Cost	
SPELDUR	Spell duration (5n, days).	Difference between admission date and discharge data **data minimisation**	
BEDYEAR	Number of bed days in the year (3n)	Determine number of bed days	
ADMISORC	Where admitted from (2n code)	To determine if patients discharged to existing location or new care location (comparison with DISDEST)	
DISDET	Destination on discharge (2n, code)	Discharge destination to enable determination of if patient discharged to normal residence or change.	
A&E DATA SET			
ARRIVALDATE	Arrival Date (dd/mm/yyyy)	Enable calculation of use of A&E resources	
DIAG_NN	A&E diagnosis (6n)	Map frequent diagnoses.	
DIAG2_NN	2character diagnoses	?which best.	
PSUEDO_HESID	Pseudo HES-ID (10n)	Enable matching	
AEATTENDCAT	Attendance category (1n) (1 = First A&E, 2=Follow up – planned, 3= follow up – unplanned, 9 = not known)	Determine if intentional follow up.	
AEATTENDDISP	Attendance disposal (2n, code)	?Admitted to hospital from A&E attendance	
HESID	Patient identifier	Map	
Outpatient DATA SET			
APPTDATE	Appointment date (dd/mm/yyyy)	Date of OP appointment	
ATENTYPE	Attendance type (2n, code)	Determine if first appointment/ follow up	
ATTENDED	Attended or DNA (1n, code)	Determine if attended.	
DIAG_NN	Diagnosis (6n, as above)	Determine diagnosis from OP	
HESID	Patient identifier	Map	
MAINSPEF	Main specialty (3n, code)	?Specialty seeing in clinic	
OUTCOME	Outcome of attendance (1n,code)	?further appointment required	

Unclear if these are useful variables for constructing spells			
P_Spell_Epiorder	Episode Order	1 = first up to n	
P_Spell_First_Episode	Identify the first episode within a spell	Y	
P_Spell_Last_Episode	Identify the last episode within a spell	Y	
P_Spell_Admidate	?Better than ADMIDATE	Whole spell vs. Episode	
P_Spell_Admimethod	?Better than ADMIMETHOD	Whole spell vs. Episode	
P_Spell_Disdate	?Better than DISDATE	Whole spell vs. Episode	
P_Spell_Disdest	?Better than DISDEST	Whole spell vs. Episode	
HESED_Mapped	To generate spell	Unclear if this is a better approach	

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Appendix B: OPCS4 codes to select surgical procedures

A13	K78	T57	G61	M61	D12	P25	A42	K29	V31
A14	L31	T59	G63	M62	D13	P29	A43	K30	V32
A33	L35	T60	G67	M72	D14	P32	A44	K31	V33
A59	L39	T62	G68	M73	D15	Q02	A45	K32	V34
A60	L43	T64	G69	M75	D16	Q05	A47	K33	V35
A61	L47	T65	G70	N05	D17	Q09	A48	K34	V36
A62	L54	T67	G71	N06	D20	Q10	A49	K36	V37
A63	L63	T68	G72	N26	D22	Q11	A51	K37	V38
A64	L66	T69	G73	O05	D23	Q16	A57	K38	V39
A65	L71	T70	G74	O06	D24	Q17	B01	K40	V40
A66	L73	T71	G76	O07	D26	Q19	B02	K41	V41
A67	L76	T72	G78	O08	D28	Q20	B04	K42	V42
A68	L82	T74	G82	O09	E02	Q26	B06	K43	V43
A69	L83	T79	H01	O10	E03	Q27	B08	K44	V44
A70	L84	T80	H02	O15	E04	Q28	B09	K45	V45
A73	L85	T83	H03	O17	E05	Q29	B10	K46	V46
A75	L86	T86	H04	O18	E07	Q30	B12	K47	V48
A76	L87	T87	H05	O20	E08	Q31	B14	K48	V49
A77	L88	T88	H06	O21	E09	Q32	B16	K52	V52
A78	L89	T91	H07	O22	E10	Q34	B17	K53	V54
A79	L91	T92	H08	O23	E11	Q35	B18	K54	V56
A81	L93	T96	H09	O24	E14	Q36	B20	K55	V57
A84	L94	T97	H10	O25	E15	Q37	B22	K56	V58
B30	L96	T98	H11	O26	E16	Q38	B23	K57	V60
B31	L97	V21	H12	O27	E17	Q39	B25	K66	V61
B33	L98	V47	H13	O29	E20	Q41	B27	K67	V66
B34	L99	V62	H14	P05	E24	Q49	B28	K69	V67
B35	M09	V63	H15	P17	E27	Q50	B29	K71	V68
B36	M10	W01	H16	P18	E34	Q51	B38	L01	W05
B37	M13	W02	H17	P20	E35	Q52	B39	L02	W06
B40	M15	W03	H19	P31	E38	Q54	C01	L03	W08
C02	M16	W04	H29	Q01	E48	Q56	C05	L04	W09
C03	M19	W07	H30	Q07	E50	R01	D10	L05	W10
C06	M26	W11	H33	Q08	E63	R02	D19	L06	W15
C08	M27	W12	H34	Q22	F01	R04	E01	L07	W16
C09	M28	W13	H35	Q23	F02	R05	E12	L08	W17
C10	M29	W14	H36	Q24	F03	R07	E13	L09	W18
C11	M32	W26	H40	Q25	F04	R08	E19	L10	W19
C12	M33	W29	H41	Q43	F05	R10	E21	L12	W20
C13	M38	W31	H46	Q44	F06	R12	E23	L13	W21
C14	M39	W32	H47	Q45	F09	R17	E28	L16	W22
C15	M41	W33	H49	Q47	F11	R18	E29	L18	W23
C16	M42	W34	H62	S17	F18	R28	E30	L19	W24
C17	M43	W59	J01	S18	F24	R29	E31	L20	W25
C18	M44	W68	J02	S19	F26	R30	E33	L21	W27
C19	M48	W69	J03	S20	F29	R34	E39	L22	W28
C20	M49	W70	J04	S54	F30	S01	E40	L23	W30

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C22	M53	W71	J05	S55	F32	S02	E41	L25	W37
C24	M54	W72	J07	T01	F34	S03	E42	L26	W38
C25	M55	W73	J08	T02	F36	S04	E43	L27	W39
C26	M56	W74	J16	T03	F40	S05	E44	L28	W40
C27	M58	W75	J18	T05	F42	S06	E46	L29	W41
C29	M60	W76	J19	T07	F44	S10	E47	L30	W42
C31	M64	W77	J20	T08	F45	S11	E52	L33	W43
C32	M65	W78	J21	T09	F46	S21	E53	L34	W44
C33	M66	W79	J23	T10	F48	S22	E54	L37	W45
C34	M67	W81	J27	T14	F50	S23	E55	L38	W46
C35	M68	W82	J28	T15	F51	S24	E57	L41	W47
C37	M70	W83	J29	T16	F52	S25	E59	L42	W48
C39	M71	W84	J30	T17	F53	S26	E61	L45	W49
C40	M76	W85	J31	T28	F58	S27	E62	L46	W50
C41	M79	W86	J32	T30	G14	S28	F22	L48	W51
C43	M81	W87	J33	T33	G17	S30	F23	L49	W52
C44	M83	W88	J37	T34	G75	S31	F28	L50	W53
C45	M86	W89	J52	T36	H42	S33	F38	L51	W54
C46	N01	W91	J54	T37	H44	S34	F39	L52	W55
C47	N03	W92	J55	T38	H48	S35	G01	L53	W56
C49	N07	W99	J56	T39	H50	S36	G02	L56	W57
C51	N08	X11	J57	T41	H51	S37	G03	L57	W58
C52	N09	X12	J58	T50	H52	S38	G04	L58	W60
C53	N10	X27	J59	T51	H53	S39	G05	L59	W61
C54	N11	X46	J60	T52	H54	S40	G06	L60	W62
C55	N13	X53	J61	T53	H55	S41	G07	L62	W63
C57	N15	X55	J62	T56	H56	S42	G08	L65	W64
C59	N17	A01	J63	T76	H57	S47	G09	L67	W65
C60	N18	A02	J65	T77	H58	S48	G10	L68	W67
C61	N19	A03	J68	T85	H59	S49	G11	L69	W80
C62	N20	A04	J69	T89	H60	S56	G13	L70	W93
C64	N22	A05	J70	T94	H66	S57	G21	L74	W94
C65	N24	A07	J72	V01	J06	S60	G23	L75	W95
C66	N27	A08	K01	V03	J10	S62	G24	L77	W96
C67	N28	A09	K02	V04	J11	S64	G25	L79	W97
C69	N29	A10	K04	V05	J12	S66	G27	L80	W98
C71	N30	A11	K05	V06	J13	S68	G28	L81	X01
C72	N32	A12	K06	V07	J15	S70	G29	L90	X02
C73	N34	A16	K07	V08	J24	T11	G30	M01	X03
C74	O01	A17	K08	V09	J25	T12	G31	M02	X05
C75	O02	A18	K09	V10	J26	T13	G32	M03	X07
C77	O03	A20	K10	V11	J34	T19	G33	M04	X08
C79	O04	A22	K11	V13	J35	T20	G34	M05	X09
C80	O19	A24	K12	V14	J36	T21	G35	M06	X10
C81	P01	A25	K13	V15	J49	T22	G36	M08	X14
C82	P03	A26	K14	V16	J73	T23	G38	M17	X15
C83	P06	A27	K15	V17	J77	T24	G40	M18	X17
C84	P07	A28	K17	V19	K16	T25	G41	M20	X19
C85	P09	A29	K18	V20	K35	T26	G48	M21	X20

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C86	P11	A30	K19	V22	K59	T27	G49	M22	X21
C88	P13	A31	K20	V23	K60	T29	G50	M23	X22
C89	P14	A32	K22	V24	K62	T31	G51	M25	X23
D01	P15	A34	K23	V25	K64	T42	G52	M34	X24
D02	P19	A36	K24	V26	K65	T43	G53	M35	X25
D03	P21	A38	K25	V27	K68	T45	G57	M36	X45
D04	P22	A39	K26	V28	K75	T48	G58	M37	
D06	P23	A40	K27	V29	K76	T54	G59	M51	
D08	P24	A41	K28	V30	K77	T55	G60	M52	

APPENDIX C: ICD-10 codes defining co-morbid diseases. Derived from National Clinical Coding Standards ICD-10 5th Edition 2017 and Quan et al 2005).

Disease	**ICD-10 code (used since 1995)**	
Unknown disease	R69	**Charlson**
Myocardial infarction	I21.x, I22.x, I25.2	**Charlson**
Congestive heart failure	I09.9, I11.0, I13.0, I13.2, I25.5, I42.0, I42.5–I42.9, I43.x, I50.x, P29.0	**Charlson**
Peripheral vascular disease	I70.x, I71.x, I73.1, I73.8, I73.9, I77.1, I79.0, I79.2, K55.1, K55.8, K55.9, Z95.8, Z95.9	**Charlson**
Cerebro-vascular disease	G45.x, G46.x, H34.0, I60.x–I69.x	**Charlson**
Dementia	F00.x–F03.x, F05.1, G30.x, G31.1	**Charlson**
Chronic pulmonary disease	I27.8, I27.9, J40.x–J47.x, J60.x–J67.x, J68.4, J70.1, J70.3	**Charlson**
Rheumatic disease	M05.x, M06.x, M31.5, M32.x–M34.x, M35.1, M35.3, M36.0	**Charlson**
Peptic ulcer disease	K25.x–K28.x	**Charlson**
Mild liver disease	B18.x, K70.0–K70.3, K70.9, K71.3–K71.5, K71.7, K73.x, K74.x, K76.0, K76.2–K76.4, K76.8, K76.9, Z94.4	**Charlson**
Diabetes without complications	E10.0, E10.1, E10.6, E10.8, E10.9, E11.0, E11.1, E11.6, E11.8, E11.9, E12.0, E12.1, E12.6, E12.8, E12.9, E13.0, E13.1, E13.6, E13.8, E13.9, E14.0, E14.1, E14.6, E14.8, E14.9	**Charlson**
Diabetes with complications	E10.2–E10.5, E10.7, E11.2–E11.5,E11.7, E12.2–E12.5, E12.7, E13.2–E13.5, E13.7, E14.2–E14.5, E14.7	**Charlson**
Hemiplegia or paralysis	G04.1, G11.4, G80.1, G80.2, G81.x, G82.x, G83.0–G83.4, G83.9	**Charlson**
Renal disease	I12.0, I13.1, N03.2–N03.7, N05.2–N05.7, N18.x, N19.x, N25.0, Z49.0–Z49.2, Z94.0, Z99.2	**Charlson**
Any malignancy, aside from skin.	C00.x–C26.x, C30.x–C34.x, C37.x–C41.x, C43.x, C45.x–	**Charlson**

	C58.x, C60.x–C76.x, C81.x–C85.x, C88.x, C90.x–C97.x	
Moderate or severe liver disease	I85.0, I85.9, I86.4, I98.2, K70.4, K71.1, K72.1, K72.9, K76.5, K76.6,K76.7	**Charlson**
Metastatic solid tumour	C77.x–C80.x	**Charlson**
HIV/AIDS	B20.x–B22.x, B24.x	**Charlson**
Hypertension	I10.x	**Other comorbid**
Hypertension with complications	I11.x–I13.x, I15.x	**Other comorbid**

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	N	One year mortality
Age		
18-30		
30-40		
40-50		
50-60		
60-70		
70-80		
80-90		
>90		
Sex		
Female		
Male		
Procedure grouping		
Orthopaedics		
Hepatopancreatobiliary		
Upper gastrointestinal		
Lower gastrointestinal		
Cardiac		
Thoracic		
Gynaecology		
Plastics		
Breast		
Endocrine		
Vascular		
Urology and kidney		
Head and neck		
Other		
Long-term disease		
Hypertension		
Diabetes mellitus		
Chronic lung disease		
Ischemic heart disease		
Hypercholesterolemia		
Cancer		
Stroke		
Liver disease		
HIV		
Cardiac failure		
Dementia		
Ethnicity		
White		
Black		
Asian		
Other		
Missing/NA		
Index of multiple deprivation		

Q1 – most deprived		
Q2		
Q3		
Q4		
Q5 – least deprived		

Table 1. The number of patients and proportion of patients dying within one year of index surgery, presented for each variable considered for model inclusion. Data are presented as n(%) and include pooled data from England, Scotland and Wales.

Risk decile:	N	Mean (SD) age	1 year death
1 – lowest risk			
2			
3			
Etc..			

Table 2. Outcomes of included patients, divided according to urgency of surgery. Data are n (%) unless otherwise stated. SD; standard deviation. Data will be pooled for England, Scotland and Wales.

Variable	Unadjusted OR	Adjusted OR	P value
Age			
Sex = female			
Procedure grouping			
Etc			

Table 3. Multi-level logistic regression including both unadjusted and adjusted results for 90 day death. Adjusted models include the following variables… Data from England only.

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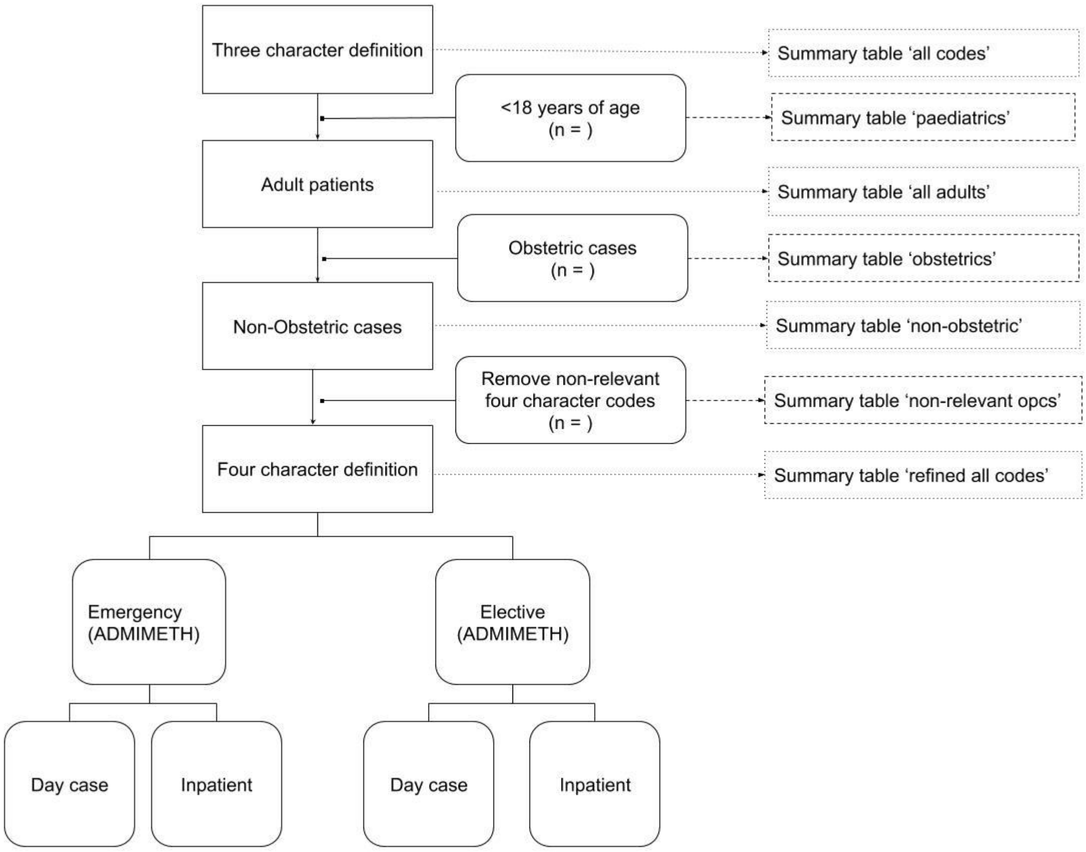
Sample figures:



Sample Figure 1. Flow diagram of patient selection. Reasons for exclusion are provided on the right hand side and final study population includes those undergoing a surgical procedure meeting a previously defined categorisation of surgery. ADMIMETH; Admission method.

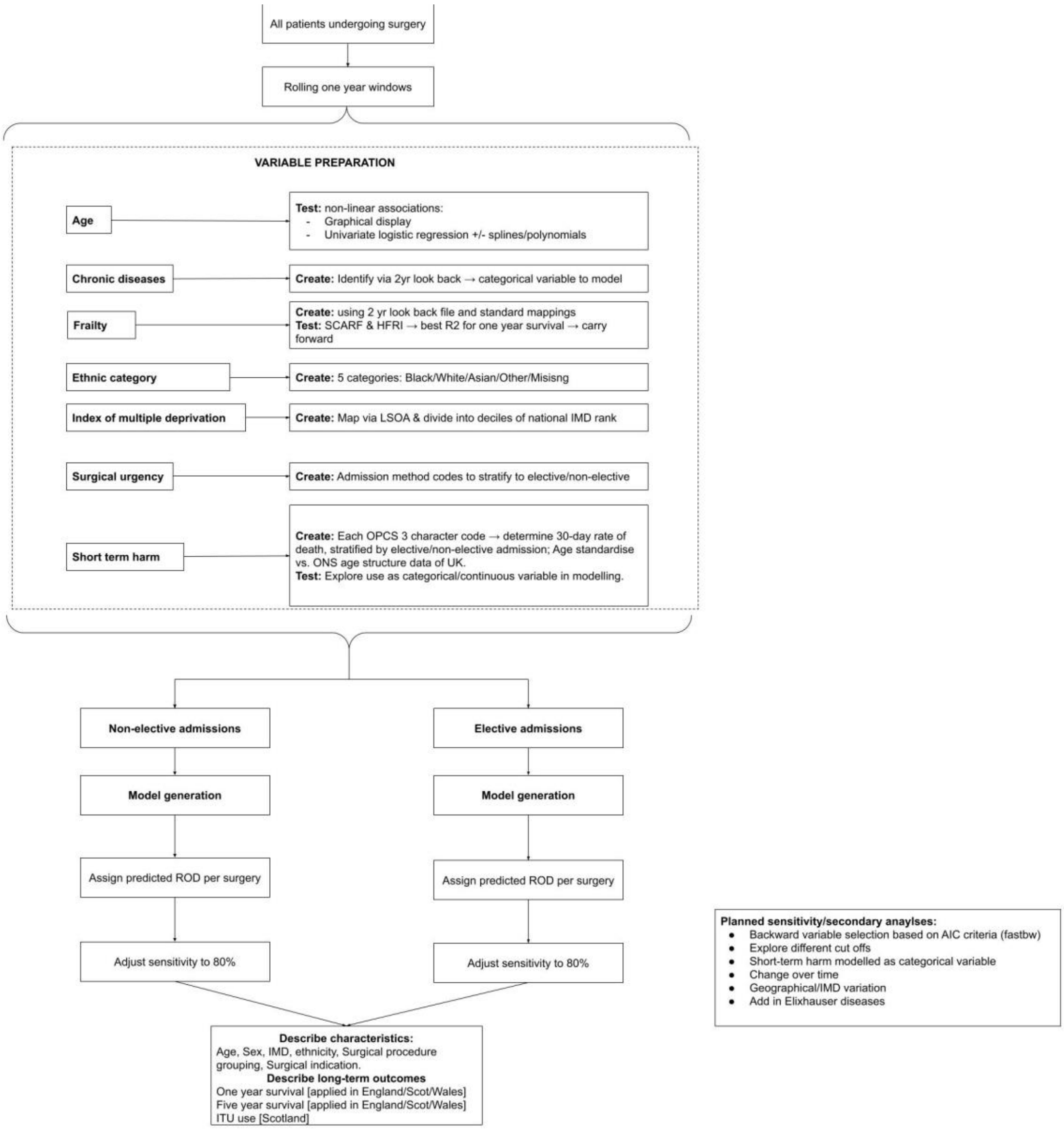


Figure 2. Anticipated statistical analysis flow.