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Pre-existing medical conditions as predictors of adverse events in day-case surgery

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We have developed mathematical models to estimate the risk of perioperative adverse events in patients with pre-existing conditions undergoing day-case surgery. We studied 17 638 consecutive day-case surgical patients in a prospective study. Preoperative, intraoperative and postoperative data were collected. Risk modelling was performed with backward stepwise multiple logistic regression and validated on a separate subset of our patients. Eighteen pre-existing conditions were entered into the model. We adjusted for age, sex, and duration and type of surgery. Seven associations between pre-existing medical conditions and perioperative adverse events were statistically significant. Hypertension predicted the occurrence of any intraoperative event and intraoperative cardiovascular events. Obesity predicted intraoperative and postoperative respiratory events, and smoking and asthma predicted postoperative respiratory events. Gastro-oesophageal reflux predicted intubation-related events. The presented models of risk estimation were validated internally and provided a useful tool for accurate risk estimation.

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Currently, more than 60% of surgical procedures in North America are performed in day-case units. Day-case surgery is gaining in popularity because of its substantial cost saving and convenience for both patients and health care providers. With improvement in anaesthetic and surgical techniques, selection criteria for day-case surgery are becoming less rigid, and more patients with multiple pre-existing medical conditions are undergoing day-case surgery.

Patients with multiple pre-existing conditions may have a higher risk of perioperative adverse events. Results from inpatient studies have shown that ASA physical status, history of ventricular arrhythmia, angina, hypertension, previous myocardial infarction, severe bronchopulmonary disease, asthma, obesity and smoking are predictors of perioperative adverse outcomes.[1–5] Earlier studies on day-case surgery usually focused on estimating the frequency of adverse outcomes,[6–9] without identifying predictors. More recent studies on day-case surgery identified predictors for unanticipated admission, delayed discharge and readmission.[10–14] One previous study focused on the associations between patients' pre-existing medical conditions and the risk of developing perioperative adverse events in day-case surgery.[15] Respiratory disease, hypertension, arrhythmia, gastrointestinal and neurological diseases, diabetes, obesity and smoking were identified as predictors of perioperative events. However, these predictors were not validated. The sample size of 6914 patients, although combined from four Canadian centres, was inadequate to yield sufficient numbers of outcomes.

Using a large patient population, we examined the association of various pre-existing medical conditions with perioperative adverse events. Our goal was to develop multivariable statistical models for accurate risk assessment.

Patients and methods

Patient population and data collection

After obtaining approval from our Institutional Ethics Committee, we conducted a prospective, observational study over a 3-yr period. Data were collected on 17 877 consecutive day-case surgical patients in the ambulatory surgery unit of Toronto Hospital, Western Division. As this was an observational study with no deviation from standard care, the Ethics Committee did not require written consent from patients before data collection. We excluded 239 patients because of cancelled surgery or missing data.

The attending anaesthetists completed specifically

designed anaesthesia records for each patient. These records included information on patient characteristics, such as age, sex, weight, height, ASA status, pre-existing medical conditions, type of surgical procedure, duration and type of anaesthesia, physiological variables and drugs given. The clinical management of the patients was left to the discretion of the anaesthetist.

Intraoperative adverse events (i.e. those occurring in the operating room (OR)) were documented by the anaesthetists on a standardized event sheet. The event sheet contained a list of adverse events accompanied by concise definitions. Intraoperative adverse events included: intubation-related events such as difficult intubation (i.e. more than two attempts), blocked tracheal tube, unplanned intubation, oesophageal intubation, unintentional extubation and dental damage; respiratory events such as desaturation, laryngospasm, bronchospasm, aspiration, apnoea and pneumothorax; fluid and metabolic events; cardiovascular events such as hypertension, hypotension, cardiac ischaemia, bradycardia, tachycardia, arrhythmia and cardiac arrest; neurological events such as excessive preoperative sedation, excessive agitation and seizure; and miscellaneous events such as muscle rigidity, drug incident, anaphylaxis, malignant hyperthermia crisis and skin injury.

Postoperative adverse outcomes (i.e. those occurring during the patient's stay in the post-anaesthesia care unit (PACU) and in the ambulatory surgical unit (ASU)) were documented by trained nursing staff on standardized event sheets. The PACU and ASU event sheets contained a list of adverse events accompanied by concise definitions. The documented adverse events in the PACU event sheet included: respiratory events such as desaturation, hypoventilation, upper airway obstruction, pulmonary oedema, bronchospasm, pneumothorax and aspiration; fluid, renal and metabolic events such as hypovolaemia, oliguria, urinary retention and abnormal blood work; cardiovascular events such as hypertension, hypotension, cardiac ischaemia, bradycardia, tachycardia, arrhythmia and cardiac arrest; neurological events such as excessive pain, excessive agitation, residual paralysis, sensory deficit, seizure, confusion and excessive sedation; and miscellaneous events such as nausea and vomiting, hypothermia, shivering, anaphylaxis, excessive bleeding and other surgical complications.

The adverse events documented on the ASU event sheet included nausea and vomiting, pain and aches, dizziness, drowsiness, cardiovascular events, excessive bleeding and miscellaneous events such as chills and fever. Duration of stay, and type and amount of medication given in the PACU and ASU were also documented. Patients were discharged when they achieved a score of 9 or 10 in the post-anaesthesia discharge scoring system.[16] Patient records and event sheets were systematically reviewed and checked for completeness and consistency on the next day by a research assistant and an experienced anaesthetist (F. C.).

Statistical analysis

Intraoperative adverse events were grouped into the following categories: any event in the OR and cardiovascular, respiratory and intubation-related events in the OR. Postoperative adverse events occurring in the PACU and ASU, although reported in separate tables to give a better view of our data, were combined in the analysis to gain statistical power and avoid sparse data. If a patient developed the same event in both the PACU and ASU, it counted only once. The following categories of postoperative adverse events were included in the analysis: any postoperative event; cardiovascular and respiratory events; pain; nausea and vomiting; drowsiness; shivering; excessive agitation; and dizziness. Incidence rates of specific adverse events according to specific pre-existing medical conditions and patient and procedure characteristics were summarized by frequency and percentage.

To determine if there was an association between specific pre-existing conditions and intraoperative and postoperative adverse events, the various pre-existing conditions and other clinically important variables were entered as predictor variables into a backward stepwise multiple logistic regression. The initial selection of variables was based on the clinical judgement of the investigators and degree of correlation between the independent variables. ASA status, by definition, was determined by the presence of pre-existing medical conditions and thus was highly correlated with the occurrence of the various conditions. As the pre-existing medical conditions were the most interesting predictor variables, we decided not to enter ASA status into the model. Similarly, type of anaesthesia was not controlled for, as this was determined mostly by the type of surgery. Therefore, only type of surgery was entered into the model. At the end of the analyses, we repeated the analyses by entering into the model the type of anaesthesia instead of the type of surgery, and we obtained similar results.

To validate our statistical models, our patient population was divided randomly into two equal halves: a model development set and a model validation set. The development set was used to develop our statistical models for prediction of perioperative adverse events. Thirteen models were developed to estimate the risk of any intraoperative event, and intraoperative cardiovascular, respiratory and intubation-related events; any postoperative event, and cardiovascular events, respiratory events, pain, nausea and vomiting, drowsiness, shivering, excessive agitation and dizziness in the postoperative period. For model development of intubation-related events, only patients undergoing general anaesthesia were included as non-general anaesthesia patients were not at risk of developing this type of adverse event. Eighteen pre-existing conditions were entered into each model (see Table 3). The models were adjusted for the effects of age, sex and type of surgery. Duration of surgery was also included in models predicting postoperative adverse events. For intraoperative adverse events, duration

was not included as prolongation of surgery could be an effect rather than a cause of an intraoperative adverse event.

Age and duration of surgery were represented by continuous variables, sex by one dummy variable, and type of surgery, grouped into nine major categories, by eight dummy variables. The variables for age, sex and type of surgery, and for models of postoperative events, and also the variable for duration of surgery, were forced into the models even if they were not otherwise included in the stepwise model, so that we could control for these factors uniformly in each model. To adjust for multiple comparisons, we set the significance level for the parameter estimate at 0.001.

Using the final predictive models with significant predictors obtained from the development set of patients, the probability of the specific adverse events were calculated for each patient in the validation set. Based on these calculated (predicted) probabilities and the patient's actual experience in the validation set (i.e. whether or not they experienced the specific adverse event) a receiver operating characteristic (ROC) curve was plotted for each model and the area under the ROC curves were calculated according to a method described by Hanley and McNeil.[17] The area under the ROC curve was used as a measure of the accuracy of the final prediction models. All analyses were carried out using SAS (version 6.12) software.

Results

Characteristics of patients and procedures

Mean age of the 17 638 patients was 47 (range 11–98) yr. Two-thirds of patients were female (11 826) and most (93.5%) were ASA I (9194) or II (7301). Almost 90% of patients underwent ophthalmic (6372), gynaecological (5959) or orthopaedic (3179) procedures. Ninety-three percent of patients underwent either general anaesthesia (10 110) or monitored anaesthesia care (anaesthetist administered sedation) (6301); only 7% received local or regional anaesthesia or chronic pain block. The surgical procedures lasted for 52 (SD 44) min and patients stayed for 51 (26) min and 98 (56) min in the PACU and ASU, respectively. A total of 599 patients developed adverse events in the OR, 1516 in the PACU and 1052 in the ASU.

Table 1 presents the incidence of intraoperative and postoperative adverse events by age, ASA status, type of anaesthesia and type of surgery. The crude rates of intraoperative adverse events increased with increasing ASA status. Patients who were ASA II or III experienced a three- to five-fold higher incidence of intraoperative adverse events than ASA I patients (unadjusted relative risks 3.1 and 5.1, respectively). The most frequent intraoperative adverse events were cardiovascular (508 events; 2.9 events per 100 operations). However, there was an inverse association between the frequency of postoperative adverse events and ASA status in both the PACU and ASU. Patients who were ASA II and III had a lower risk of postoperative adverse events than ASA I patients (unadjusted relative risks 0.75 and 0.56, respectively, in the PACU; 0.79 and 0.43, respectively, in the ASU). The most frequent postoperative adverse events were excessive pain (836 events (4.7 events per 100 operations) in the PACU and 335 events (1.9 events per 100 operations) in the ASU) and nausea and vomiting (385 events (2.2 per 100 operations) in the PACU and 685 events (3.9 events per 100 operations) in the ASU).

The frequency of intraoperative adverse events increased linearly with increasing age. The frequency of postoperative adverse events, after a slight increase with age in patients less than 40 yr of age, showed a decreasing tendency with increasing age.

For intraoperative adverse events, the highest frequencies were observed in ophthalmic (5.4%), urological (5.2%) and ENT–dental patients (4.7%), whereas the lowest frequencies were observed in patients undergoing gynaecological procedures (1.4%) or chronic pain block (1.3%). For PACU and ASU adverse events, the highest frequencies were observed in orthopaedic patients (20% and 10%, respectively) and ENT–dental patients (14% and 20%, respectively), whereas the lowest frequencies were observed in patients undergoing ophthalmic procedures (2.6% and 4.2%, respectively) or chronic pain block (4.5% and 3.2%, respectively).

Patients undergoing monitored anaesthesia care experienced the highest rate of intraoperative adverse events. The unadjusted relative risks for intraoperative events during general, local and regional anaesthesia, and chronic pain block compared with monitored anaesthesia care were 0.6, 0.1, 0.4 and 0.3, respectively. For postoperative adverse events, the risk was higher in patients undergoing general anaesthesia (unadjusted relative risks 9.1 and 3.0 in the PACU and ASU, respectively), regional anaesthesia (unadjusted relative risks 3.5 and 0.8 in the PACU and ASU, respectively) and chronic pain block (unadjusted relative risks 3.0 and 1.1 in the PACU and ASU, respectively) compared with patients who underwent monitored anaesthesia care.

The frequency of intraoperative and postoperative adverse events showed a sharp increase with duration of the procedures, except for very long procedures (those lasting more than 3 h) (Fig. 1). However, only 40 patients underwent extremely long procedures.

Pre-existing medical conditions

Fifty-four per cent of the 17 638 patients had one or more pre-existing medical conditions in their medical history. Twenty-eight per cent of patients had one condition, 15% had two, 6% had three and less than 5% of patients presented with more than three conditions. Obesity (defined as body mass index >30 kg m^{-2}), smoking and hypertension were the most frequent categories (14–16%) (Table 2). Arthritis, asthma and diabetes mellitus each appeared in the medical histories of more than 5% of patients. In addition to these conditions, thyroid disease, angina pectoris, gastro-oesophageal reflux and arrhythmia were among the 10

Table 1 Incidence of intraoperative and postoperative adverse events by age, ASA status, type of anaesthesia and type of surgery. Intraoperative adverse events were those occurring in the operating room (OR) while postoperative adverse outcomes were those occurring during the patient's stay in the post-anaesthesia care unit (PACU) and in the ambulatory surgical unit (ASU)

Characteristic/procedure	No.	Any OR event (No. (%))	Any PACU event (No. (%))	Any ASU event (No. (%))
Age (yr)				
⩽20	1429	20 (1.4)	146 (10.2)	85 (6.0)
21–30	3873	71 (1.8)	421 (10.9)	247 (6.4)
31–40	3319	73 (2.2)	421 (12.7)	297 (9.0)
41–50	1944	46 (2.4)	225 (11.6)	169 (8.7)
51–60	1538	64 (4.2)	132 (8.6)	101 (6.6)
61–70	2060	88 (4.3)	89 (4.3)	78 (3.8)
71–80	2297	126 (5.5)	62 (2.7)	59 (2.6)
81–90	1110	106 (9.6)	20 (1.8)	15 (1.4)
⩾91	68	5 (7.4)	0 (0.0)	1 (1.5)
ASA status				
I	9194	147 (1.6)	911 (9.9)	627 (6.8)
II	7301	359 (4.9)	542 (7.4)	392 (5.4)
III	1143	93 (8.1)	63 (5.5)	33 (2.9)
Type of anaesthesia				
General	10 110	287 (2.8)	1387 (13.7)	838 (8.3)
Monitored anaesthesia care				
(i.v. conscious sedation)	6301	297 (4.7)	95 (1.5)	175 (2.8)
Local	586	3 (0.5)	2 (0.3)	20 (3.4)
Regional	484	10 (2.1)	25 (5.2)	14 (2.2)
Chronic pain block	157	2 (1.3)	7 (4.5)	5 (3.2)
Type of surgery				
Ophthalmic	6372	345 (5.4)	163 (2.6)	266 (4.2)
Gynaecological	5959	83 (1.4)	468 (7.9)	292 (4.9)
Orthopaedic	3179	110 (3.5)	628 (19.8)	321 (10.1)
Plastic	633	16 (2.5)	76 (12.0)	56 (8.9)
Neurosurgery	484	11 (2.3)	57 (11.8)	21 (4.3)
General	398	10 (2.5)	52 (13.1)	31 (7.9)
ENT–dental	224	10 (4.7)	32 (14.3)	45 (20.0)
Urological	232	12 (5.2)	31 (13.4)	15 (7.0)
Chronic pain block	157	2 (1.3)	7 (4.5)	5 (3.2)

most frequent conditions. The crude incidence rates of intraoperative and postoperative adverse events by the various pre-existing medical conditions are shown in Tables 3–5. Patients with congestive heart failure had the highest frequency of intraoperative events, followed by patients with hypertension and those with past cerebrovascular events. Most of the adverse events in the OR were cardiovascular (Table 3). In the PACU, patients with a history of seizure had the highest frequency of adverse events, mainly excessive postoperative pain. Patients with asthma, valvular heart disease or upper respiratory tract infection, and smokers and obese patients had a greater than 10% frequency of adverse events in the PACU (Table 4). In the ASU, patients with upper respiratory infection had the highest incidence of adverse events, followed by patients with valvular heart disease and a history of seizures (Table 5). Most of the adverse events in the PACU and ASU were excessive postoperative pain, and nausea and vomiting.

Model development and validation

The characteristics of the development and validation sets were similar. There were no significant differences between the two groups. Of the 13 models for perioperative adverse events, five included significant predictor variables representing pre-existing medical conditions (see appendix). For any intraoperative event and for intraoperative cardiovascular events, patients with hypertension had an approximate two-fold increase in risk (adjusted odds ratios 2.2 and 2.5, respectively) (Table 6). For intraoperative respiratory events, obese patients were approximately four times more likely to develop such events (adjusted odds ratio 3.9). The type of intraoperative cardiovascular events in patients with hypertension and type of intraoperative respiratory events in obese patients are shown in Table 7. For intubation-related events, patients with gastro-oesophageal reflux experienced a nine-fold increase in risk (adjusted odds ratio 8.0). In the total population, 11 patients had intubation-related events in those with a history of gastro-oesophageal reflux. For eight of these, intubation was difficult, in two cases unplanned intubation and in one case oesophageal intubation occurred.

Of the postoperative adverse events, only respiratory adverse events were significantly associated with pre-existing medical conditions. For postoperative respiratory events, patients with asthma, obese patients and smokers had an approximately four-fold increase in the risk of developing such events (adjusted odds ratios 4.6, 3.9 and 3.8, respectively) (Table 6). There was no significant predictor

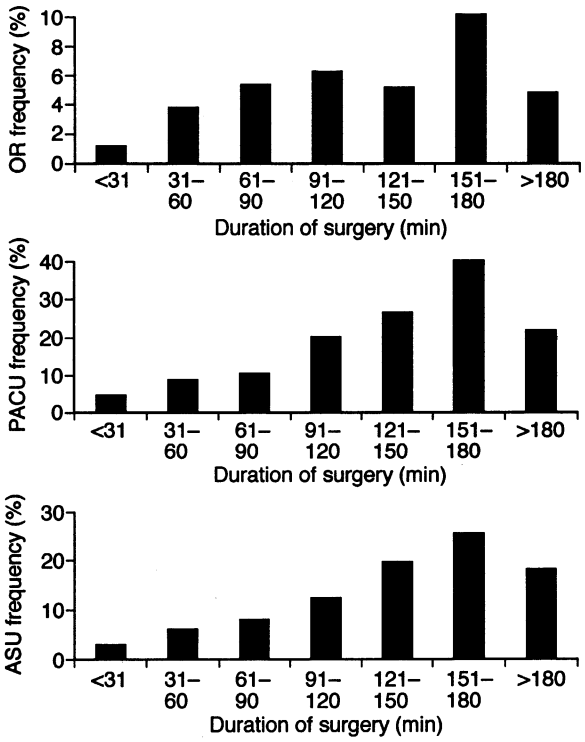

Fig 1 Frequency of intraoperative and postoperative adverse events by duration of surgery. Intraoperative adverse events were those occurring in the operating room (OR). Postoperative adverse outcomes were those occurring during the patient's stay in the post-anaesthesia care unit (PACU) and in the ambulatory surgical unit (ASU).

Table 2 Pre-existing medical conditions in the patients' medical histories. COPD=Chronic obstructive pulmonary disease; URTI=upper respiratory tract infection; GO=gastro-oesophageal; CVA=cerebrovascular attack; TIA=transient ischaemic attack; HIV=human immunodeficiency virus

Medical condition	No. (%)
Hypertension	2441 (13.8)
Angina pectoris	751 (4.3)
Myocardial infarction	449 (2.5)
Arrhythmia	471 (2.7)
Valvular heart disease	302 (1.7)
Congestive heart failure	144 (0.8)
Smoking	2508 (14.2)
Asthma	1003 (5.7)
COPD	383 (2.2)
URTI	95 (0.5)
GO reflux	644 (3.7)
Renal disease	204 (1.2)
Diabetes mellitus	921 (5.2)
Thyroid disease	790 (4.5)
Obesity	2799 (15.9)
Arthritis	1148 (6.5)
CVA or TIA	234 (1.3)
Seizure	118 (0.7)
Peptic ulcer	139 (0.8)
Hepatitis	138 (0.8)
Sickle cell trait	92 (0.5)
Substance abuse	88 (0.5)
Anaemia	46 (0.3)
HIV positive	17 (0.1)
Not specified	853 (4.8)

among the pre-existing medical conditions for any other postoperative adverse events.

Validation of the final models was completed using data from the validation set of patients. The accuracy of the five models was 0.69–0.78, as determined by the calculated area under the ROC curves (Fig. 2). The best accuracy was achieved by the model which was developed to predict intraoperative cardiovascular events. The area under the corresponding ROC curve was 0.78 (SD 0.016).

Using the final models with significant predictor variables, it is possible to estimate individual patient risk and corresponding confidence intervals (CI) based on their characteristics (age, sex, duration and type of surgery) and presence or absence of certain pre-existing medical conditions (see appendix). As an example, we have calculated the risk of intraoperative cardiovascular events (and 95% CI) for the following two hypothetical patients using formula (b). Patient No. 1, a 30-yr-old woman without hypertension undergoing a gynaecological operation:

$P=1/(1+e^{-(-5.83+0.26*3)})=0.006=0.6\%$ (0.3–1.2%)

Patient No. 2, a 70-yr-old man with hypertension undergoing a urological operation:

$P=1/(1+e^{-(-5.83+0.26*7-0.19+0.13*1+0.90*1)})=0.040=4.0\%$ (0.6–21.6%)

Thus patient No. 1 has a 0.6% chance of experiencing an intraoperative cardiovascular event and patient No. 2 has a 4.0% chance.

Similarly, using formula (e), the calculated risk of developing a postoperative respiratory event for patient No. 3, a 30-yr-old non-asthmatic, non-obese, non-smoking man undergoing a 60-min orthopaedic operation is:

$P=1/(1+e^{-(-8.50+0.16*3-0.45+0.37*2+0.90*1)})=0.001=0.1\%$ (0.01–1.1%)

For patient No. 4, a 30-yr-old obese, female smoker with a history of asthma undergoing a 60-min orthopaedic operation, the risk is:

$P=1/(1+e^{-(-8.50+0.16*3+0.37*2+0.90*1+1.53*1+1.35*1+1.35*1)})=0.104=10.4\%$ (0.9–60.3%)

Thus Patient No. 3 has a 0.1% chance of experiencing a postoperative respiratory event and patient No. 4 has a 10.4% chance.

Discussion

Selection of appropriate outcome variables, which is a prerequisite to correctly identifying relevant predictive factors, is a complex task requiring clinical insight.[18] Severe or life-threatening adverse outcomes, such as myocardial infarction or cardiac arrest, are extremely rare among day-case patients and are not the best choices for assessing the quality of day-case surgery. Unanticipated postoperative admission to intensive care units or hospital wards, prolonged postoperative stay and unscheduled return hospital visits are established indicators of the quality of day-case surgery. These outcomes convey important information regarding the quality of care and excess burden on both

Table 3 Incidence of intraoperative adverse events by pre-existing medical condition. COPD=Chronic obstructive pulmonary disease; URTI=upper respiratory tract infection; GO=gastro-oesophageal; CVA=cerebrovascular attack; TIA=transient ischaemic attack

	Any event (No. (%))	Cardiovascular event (No. (%))	Respiratory event (No. (%))	Intubation-related event (No. (%))
Hypertension	206 (8.4)	187 (7.7)	9 (0.4)	6 (0.3)
Angina pectoris	52 (6.9)	49 (6.5)	0 (0.0)	2 (0.3)
Myocardial infarction	30 (6.7)	29 (6.5)	0 (0.0)	1 (0.2)
Arrhythmia	29 (6.2)	28 (5.9)	1 (0.2)	0 (0.0)
Valvular heart disease	13 (4.3)	12 (4.0)	1 (0.3)	0 (0.0)
Congestive heart failure	16 (11.1)	16 (11.1)	0 (0.0)	0 (0.0)
Smoking	104 (4.2)	59 (2.4)	27 (1.1)	9 (0.4)
Asthma	40 (4.0)	23 (2.3)	7 (0.7)	4 (0.4)
COPD	28 (7.3)	23 (6.0)	2 (0.5)	0 (0.0)
URTI	2 (2.1)	1 (1.1)	1 (1.1)	0 (0.0)
GO reflux	32 (5.0)	20 (3.1)	6 (0.9)	10 (1.6)
Renal disease	15 (7.4)	12 (5.9)	1 (0.5)	0 (0.0)
Diabetes mellitus	55 (6.0)	51 (5.5)	0 (0.0)	2 (0.2)
Thyroid disease	43 (5.4)	34 (4.3)	1 (0.1)	5 (0.6)
Obesity	137 (4.9)	89 (3.2)	29 (1.0)	15 (0.5)
Arthritis	86 (7.5)	69 (6.0)	5 (0.4)	7 (0.6)
CVA or TIA	19 (8.1)	18 (7.7)	0 (0.0)	0 (0.0)
Seizure	5 (4.2)	4 (3.4)	1 (0.9)	0 (0.0)

Table 4 Incidence of adverse events in the PACU by pre-existing medical condition. N/V=Nausea, vomiting; COPD=chronic obstructive pulmonary disease; URTI=upper respiratory tract infection; GO=gastro-oesophageal; CVA=cerebrovascular attack; TIA=transient ischaemic attack

	Any event (No. (%))	Cardiovascular event (No. (%))	Respiratory event (No. (%))	Excessive pain (No. (%))	N/V (No. (%))
Hypertension	121 (5.0)	36 (1.5)	12 (0.5)	52 (2.1)	20 (0.8)
Angina pectoris	35 (4.7)	11 (1.5)	7 (0.9)	12 (1.6)	6 (0.8)
Myocardial infarction	19 (4.2)	6 (1.3)	1 (0.2)	6 (1.3)	2 (0.5)
Arrhythmia	20 (4.3)	5 (1.1)	3 (0.6)	4 (0.9)	8 (1.7)
Valvular heart disease	36 (11.9)	1 (0.3)	0 (0.0)	22 (7.3)	9 (3.0)
Congestive heart failure	5 (3.5)	1 (0.7)	1 (0.7)	0 (0.0)	2 (1.4)
Smoking	295 (11.8)	16 (0.6)	16 (0.6)	185 (7.4)	61 (2.4)
Asthma	127 (12.7)	4 (0.4)	13 (1.3)	57 (5.7)	46 (4.6)
COPD	14 (3.7)	3 (0.8)	4 (1.0)	4 (1.0)	1 (0.3)
URTI	11 (11.6)	1 (1.1)	0 (0.0)	6 (6.3)	3 (3.2)
GO reflux	51 (7.9)	4 (0.6)	5 (0.8)	26 (4.0)	15 (2.3)
Renal disease	14 (6.9)	2 (1.0)	1 (0.5)	8 (3.9)	0 (0.0)
Diabetes mellitus	28 (3.0)	10 (1.1)	5 (0.5)	12 (1.3)	2 (0.2)
Thyroid disease	53 (6.7)	9 (1.1)	5 (0.6)	21 (2.7)	17 (2.2)
Obesity	289 (10.3)	17 (0.6)	27 (1.0)	160 (5.7)	77 (2.8)
Arthritis	85 (7.4)	13 (1.1)	2 (0.2)	43 (3.8)	21 (1.8)
CVA or TIA	16 (6.8)	5 (2.1)	2 (0.9)	3 (1.3)	5 (2.1)
Seizure	21 (17.8)	1 (0.9)	0 (0.0)	16 (13.6)	4 (3.4)

health care providers and patients.[10–13] On the other hand, analyses using these outcome measures do not study the predictive value of preoperative factors on these outcomes; they usually concentrate on the immediate reasons behind admission, return visit or prolonged stay.

Less severe, non-life-threatening, and disease- or organ-specific perioperative adverse events are intermediate, or surrogate outcomes to the ultimate clinical outcome measures of day-case anaesthesia, such as duration of stay, unanticipated hospital admission, patient satisfaction and level of functioning after surgery. At the same time, by using these disease- or organ-specific outcomes, we are able to identify specific associations between pre-existing medical conditions and their corresponding perioperative adverse events.

Our results, in common with those of previously reported studies, showed low rates of adverse events, further supporting the belief that day-case surgery is a safe practice. The most frequent intraoperative events were cardiovascular events, and the most frequent postoperative events were related to the management of pain and nausea and vomiting.

The association between hypertension and intraoperative cardiovascular adverse events is well established in the literature.[2 15] In our study, hypertension was associated with an increased risk of intraoperative cardiovascular events. However, a similar association was not found between perioperative cardiovascular adverse events and other types of cardiac disease. There could be several explanations for this. First, the other conditions, such as angina, myocardial infarction, arrhythmia, valvular heart disease and congestive heart failure, mandated optimal control before elective surgery, whereas it is common to proceed with elective surgery even when the patient's hypertension is poorly controlled. In addition, the number of patients with these

Table 5 Incidence of adverse events in the ASU by pre-existing medical condition. COPD=Chronic obstructive pulmonary disease; URTI=upper respiratory tract infection; GO=gastro-oesophageal; CVA=cerebrovascular attack; TIA=transient ischaemic attack.

	Any event (No. (%))	Cardiovascular event (No. (%))	Excessive pain (No. (%))	Nausea, vomiting (No. (%))
Hypertension	87 (3.6)	8 (0.3)	34 (1.4)	39 (1.6)
Angina pectoris	23 (3.1)	2 (0.3)	11 (1.5)	10 (1.3)
Myocardial infarction	10 (2.2)	3 (0.7)	2 (0.5)	3 (0.7)
Arrhythmia	17 (3.6)	0 (0.0)	6 (1.3)	8 (1.7)
Valvular heart disease	25 (8.3)	1 (0.3)	8 (2.7)	9 (3.0)
Congestive heart failure	5 (3.5)	2 (1.4)	1 (0.7)	3 (2.1)
Smoking	136 (5.4)	2 (0.1)	51 (2.0)	59 (2.4)
Asthma	70 (7.0)	1 (0.1)	16 (1.6)	40 (4.0)
COPD	14 (3.7)	0 (0.0)	7 (1.8)	6 (1.6)
URTI	12 (12.6)	0 (0.0)	5 (5.3)	4 (4.2)
GO reflux	34 (5.3)	0 (0.0)	12 (1.9)	16 (2.5)
Renal disease	14 (6.9)	0 (0.0)	5 (2.5)	8 (3.9)
Diabetes mellitus	34 (3.7)	1 (0.1)	13 (1.4)	19 (2.1)
Thyroid disease	43 (5.4)	0 (0.0)	8 (1.0)	23 (2.9)
Obesity	176 (6.3)	7 (0.3)	56 (2.0)	76 (2.7)
Arthritis	65 (5.7)	2 (0.2)	20 (1.7)	30 (2.6)
CVA or TIA	8 (3.4)	1 (0.4)	3 (1.3)	3 (1.3)
Seizure	9 (7.6)	0 (0.0)	4 (3.4)	4 (3.4)

Table 6 Adjusted odds ratios (99.9% confidence intervals) of the significant predictors from the final models of the backward stepwise logistic regression. Odds ratios are adjusted for age, sex, and duration and type of surgery

Adverse event	Hypertension	Smoking	Asthma	Obesity	GO reflux
Intraoperative					
Any event	2.21 (1.37–3.58)				
Cardiovascular	2.47 (1.45–4.19)				
Respiratory				3.89 (1.14–13.3)	
Intubation related					8.00 (1.17–54.6)
Postoperative					
Respiratory		3.84 (1.11–13.3)	4.61 (1.18–18.0)	3.87 (1.12–13.3)	

Table 7 Intraoperative adverse events in patients with hypertension and obesity

	Patients with hypertension (No. (%))	Obese patients (No. (%))
Intraoperative cardiovascular		
Hypertension	174 (76.0)	
Arrhythmia	21 (9.2)	
Hypotension	14 (6.1)	
Bradycardia	13 (5.7)	
Tachycardia	7 (3.1)	
Intraoperative respiratory		
Bronchospasm		13 (36.1)
Laryngospasm/stridor		6 (16.7)
Desaturation		14 (38.9)
Aspiration		2 (5.6)
Pneumothorax		1 (2.8)

other cardiac conditions was relatively small, resulting in higher statistical uncertainty and a lower power to detect an association, despite the observed higher rate of perioperative cardiovascular events in these patients. That hypertension predicted the occurrence of any intraoperative event is probably a result of the fact that most intraoperative events were cardiovascular.

Obese patients were approximately four times more likely to develop perioperative respiratory events. Similar associations have been reported previously.[15 19] The well known adverse effect of smoking on the respiratory system explains why smokers experienced a higher incidence of postoperative respiratory events.[1 2 15] The association between asthma and postoperative respiratory events can be explained by the effect of increased stress caused by surgery provoking asthmatic symptoms. The extremely strong association between gastro-oesophageal reflux and intubation-related adverse events was probably a result of the difficulties encountered with rapid sequence events. This study indicated that assessment and preparation for the possibly difficult intubation of these patients are very important.

As our study was observational, it is not appropriate to draw causal inference concerning any of the above-described associations, and some of our explanations are speculative. We identified predictors of adverse events. However, our predictive models showed good prediction accuracy when we tested them on an independent sample of patients, yielding areas under the ROC curves of 0.69–0.78.

Our analysis included a total of 29 predictor variables (18 variables representing 18 pre-existing medical conditions and 11 variables representing age, sex, and duration and type of surgery) in each of the 13 models. According to a simulation model, 10 outcomes per predictor variable were required for a stable model.[20] Therefore, for any outcome we examined, we needed at least 290 events for

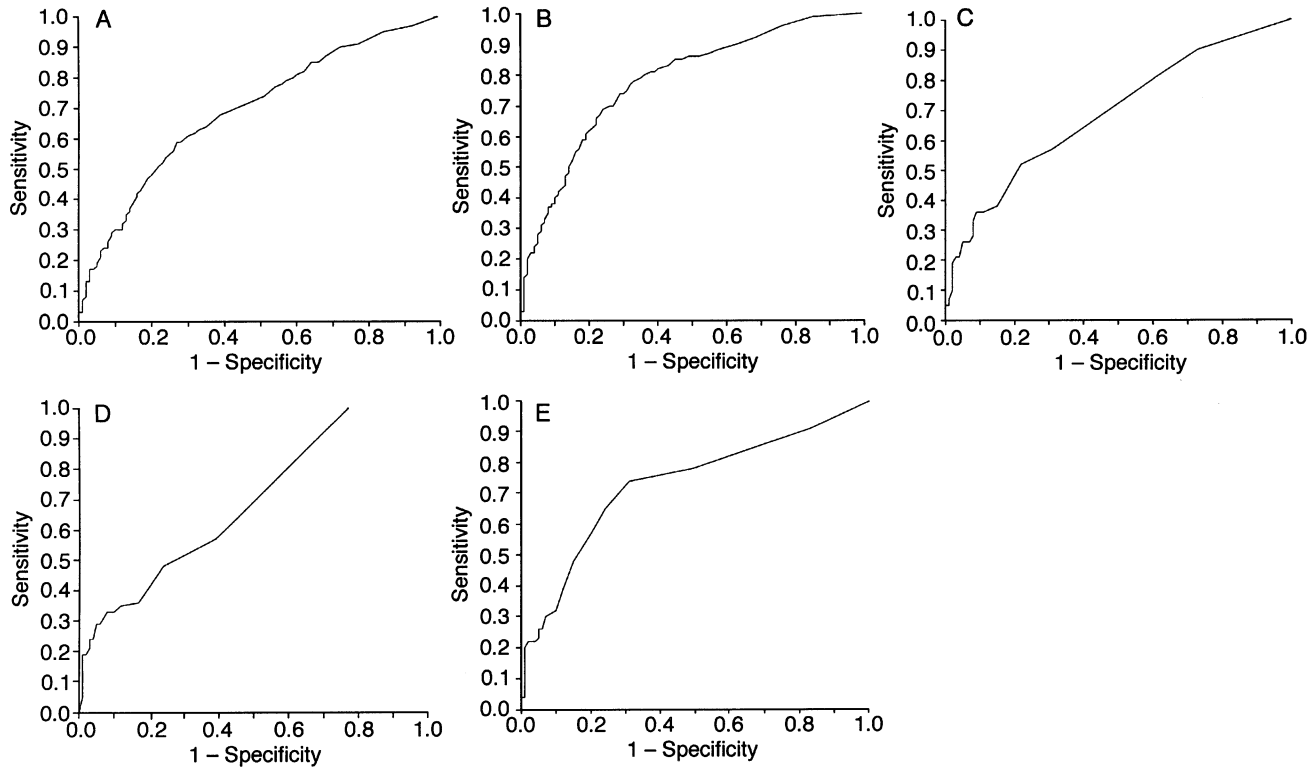

Fig 2 ROC curves for the models predicting: A: any intraoperative adverse event (area under the curve 0.694 (SD 0.016)); B: intraoperative cardiovascular adverse events (area under the curve 0.780 (0.016)); C: intraoperative respiratory adverse events (area under the curve 0.689 (0.043)); D: intubation-related adverse events (area under the curve 0.685 (0.055)); E: postoperative respiratory adverse events (area under the curve 0.730 (0.060)).

reliable prediction. The results of the modelling should be interpreted in light of the observed incidence rates. The large number of models and predictor variables examined also raised the spectre of multiple comparisons. To overcome this problem, we used 0.001 as our critical *P* value in the multiple logistic models. Although we studied close to 18 000 subjects, some of the adverse events occurred infrequently. This observed low frequency in certain outcomes, together with the conservative significance level set to overcome the problem of multiple comparisons, raised the possibility of beta errors.

In everyday practice, it is important for the anaesthetist to know which pre-existing medical condition predicts a specific intraoperative or postoperative adverse event to be able to provide the optimal care for the patient and possibly prevent the occurrence of those adverse events. In addition, it would be desirable for the anaesthetist to estimate the likelihood that a given patient with certain characteristics will develop a particular adverse event. For this reason, we have reported the odds ratios of the associations, and also provided the whole models for risk assessment to enable the reader to estimate the specific risk of an adverse event in any given patient based on the patient's characteristics.

With the growing number of day-case procedures performed world-wide, it is important to estimate the patient's risk of adverse events accurately. Ours is the first study to develop a validated model of risk estimation based on pre-existing medical conditions. Of the five predictors identified for perioperative adverse events, the most relevant for everyday clinical practice is that hypertension predicted intraoperative cardiovascular events. These findings point to the need for more careful preoperative control and perioperative management of hypertensive patients.

Appendix

Logistic regression is used to model the relationship between predictor variables and binary outcome variables. Logistic regression modelling assumes that the probability of an event (i.e. occurrence of the outcome) is associated with the values of the explanatory variables in the following way:

$$P=1/(1+e^{-\text{logit}(P)})$$

where

$$\text{logit}(P)=\beta_0+\beta_{1\times1}+\cdots+\beta_n x_n$$

where P=probability of the occurrence of the outcome; x_i=value of the ith independent variable; and β_i=parameter estimates for the ith variable. Fitting the model to the data, we can obtain the maximum likelihood estimate of the parameters for each variable. Based on the maximum likelihood estimates from the final models, it is possible to calculate an expected risk of occurrence of the specific adverse events for each patient. Below we present the five final models with significant predictors. Standard error of the parameter estimates is given in subscripts and parentheses. Age=age in years with 10-yr increment; Sex=1 if male, 0 if female; Duration=duration in minutes with 30-min increment; if type of surgery is ENT, then ENT=1 and other surgery variables=0; if type of surgery is general surgery, then General=1 and other surgery variables=0, and so on with other types of surgery; if type of surgery is gynaecological (reference group), then all surgery variables=0; hypertension=1 if hypertension is present, 0 if absent.

(a) Probability of the occurrence of any intraoperative event (P_1)

$\text{logit}(P_1) = -4.82_{(\pm 0.21)} + 0.17_{(\pm 0.04)}*\text{Age} + -0.14_{(\pm 0.14)}*\text{Sex} + 1.10_{(\pm 0.49)}*\text{ENT} + 0.19_{(\pm 0.42)}*\text{General} + -0.01_{(\pm 0.49)}*\text{Neuro} + 0.46_{(\pm 0.25)}*\text{Ophthalm} + 0.85_{(\pm 0.23)}*\text{Orthop} + 0.41_{(\pm 0.43)}*\text{Plastic} + 0.68_{(\pm 0.51)}*\text{Urological} + 0.79_{(\pm 0.79)}*\text{Hypertension}.$

(b) Probability of the occurrence of intraoperative cardiovascular event (P_2)

$\text{logit}(P_2) = -5.83_{(\pm 0.29)} + 0.26_{(\pm 0.06)}*\text{Age} + -0.19_{(\pm 0.16)}*\text{Sex} + 0.79_{(\pm 0.75)}*\text{ENT} + -0.13_{(\pm 0.63)}*\text{General} + -0.49_{(\pm 0.76)}*\text{Neuro} + 0.61_{(\pm 0.32)}*\text{Ophthalm} + 0.94_{(\pm 0.30)}*\text{Orthop} + 0.06_{(\pm 0.64)}*\text{Plastic} + 0.13_{(\pm 0.78)}*\text{Urological} + 0.90_{(\pm 0.16)}*\text{Hypertension}.$

(c) Probability of the occurrence of intraoperative respiratory event (P_3)

$\text{logit}(P_3) = -5.46_{(\pm 0.49)} + -0.14_{(\pm 0.13)}*\text{Age} + -0.21_{(\pm 0.44)}*\text{Sex} + 1.11_{(\pm 1.06)}*\text{ENT} + 0.66_{(\pm 0.78)}*\text{General} + -0.38_{(\pm 0.68)}*\text{Ophthalm} + 0.70_{(\pm 0.50)}*\text{Orthop} + 0.27_{(\pm 1.08)}*\text{Plastic} + 1.36_{(\pm 0.37)}*\text{Obesity}.$

(d) Probability of the occurrence of intubation-related event (P_4)

$\text{logit}(P_4) = -7.28_{(\pm 0.64)} + 0.32_{(\pm 0.14)}*\text{Age} + 0.07_{(\pm 0.52)}*\text{Sex} + 1.82_{(\pm 1.10)}*\text{ENT} + 0.72_{(\pm 1.08)}*\text{General} + 2.25_{(\pm 0.88)}*\text{Neuro} + -0.07_{(\pm 1.11)}*\text{Ophthalm} + 0.38_{(\pm 0.61)}*\text{Orthop} + 2.08_{(\pm 0.58)}*\text{GE reflux}.$

(e) Probability of the occurrence of postoperative respiratory event (P_5)

$\text{logit}(P_5) = -8.50_{(\pm 0.75)} + 0.16_{(\pm 0.12)}*\text{Age} + -0.45_{(\pm 0.40)}*\text{Sex} + 0.37_{(\pm 0.17)}*\text{Duration} + 1.87_{(\pm 0.98)}*\text{ENT} + 1.71_{(\pm 0.81)}*\text{General} + 0.92_{(\pm 0.97)}*\text{Neuro} + -0.07_{(\pm 0.77)}*\text{Ophthalm} + 0.90_{(\pm 0.67)}*\text{Orthop} + 0.99_{(\pm 0.96)}*\text{Plastic} + 1.53_{(\pm 0.41)}*\text{Asthma} + 1.35_{(\pm 0.38)}*\text{Obesity} + 1.35_{(\pm 0.38)}*\text{Smoking}.$

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