Hospital mortality after urgent and emergency laparotomy in patients aged 65 yr and over. Risk and prediction of risk using multiple logistic regression analysis

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Summary
We studied 107 patients aged over 65 years undergoing urgent or emergency laparotomy. Aspects of preoperative assessment, perioperative management and postoperative care were analysed by multiple logistic regression to determine the factors that predicted hospital survival. We determined which factors influenced anaesthetists' prediction that patients would survive. These predictions were made both before and immediately after operation. The factors associated with the use of invasive cardiovascular monitoring were also studied. We obtained a model that accounted for 93% of the variability in the likelihood of survival. Age and ASA status were significant predictors of survival (\( P < 0.05 \)), and of anaesthetists' prediction of mortality both before and after operation. Several other factors were significant determinants of survival but were not determinants of the anaesthetist's opinion regarding survival. (Br. J. Anaesth. 1998; 80: 776–781)

Keywords: mortality risk factors; outcome prediction; surgery laparotomy emergency

Urgent or emergency laparotomy is a common procedure and has a mortality rate considerably greater than that of elective laparotomy.1 In older patients abdominal pathology more often presents acutely;2 and mortality is greater than in younger patients.3 In one series 80% of perioperative surgical deaths were of elderly patients with abdominal pathology.4

As patients get older coincident diseases are more common. Even if there is no evidence of disease there may well be a decrease in physiological reserve (such as decreased glomerular filtration rate despite normal serum creatinine). The initial disease that requires surgery may be complicated by tissue hypoperfusion and acidosis from vomiting and loss of fluid into the gastrointestinal tract, or bleeding. Patients may be malnourished or cachectic after prolonged illness. Mortality rates are high (10–55%),1,7 but comparison between series is difficult because of differing case mixes. Eighty-six percent of deaths reported in the National Confidential Enquiry into Perioperative Deaths (NCEPOD) were of patients aged over 60 yr and 57% of the reported deaths were after urgent or emergency operations.8

We conducted a pilot study of in-hospital mortality among a cohort of patients undergoing nonsched-uled laparotomy in a district general hospital. We aimed to identify those patients at greatest risk and collect information prospectively to determine: (1) whether it is possible to predict who will die; (2) which factors predict outcome; (3) which factors influence decision making; and (4) whether these factors are the same.

Method
DATA COLLECTION
For a period of 6 months all patients at a district general hospital who underwent urgent or emergency laparotomy (NCEPOD definitions, fig. 1) entered the study. These patients were identified from emergency and elective surgical operation lists. Their management was not altered by being in the study. The senior anaesthetist treating the patient filled in a questionnaire (fig. 2) on preoperative assessment, perioperative management and postoperative care. The senior operating surgeon provided information where relevant. All information relating to preoperative assessment was collected before surgery. Before and immediately after surgery the surgeon and anaesthetist treating the patient were asked to predict patient outcome (whether or not the patient would leave hospital alive). Surgical opinion was collected by the anaesthetist completing the questionnaire without communicating his or her own opinion. Patient outcome and date of discharge from hospital or death were collected from the hospital's patient data system.

Time of operation (daytime, out of hours and night-time) was defined as NCEPOD uses the terms. ASA status was assigned by the anaesthetist according to the American Society of Anesthesiologists classification (fig. 3). Risk factors assessed before operation were summed to produce a risk factor score. Surgical procedures were classified as: (1) involving bowel resection, (2) not involving bowel resection or (3) repair of abdominal aortic aneurysm.

DATA ANALYSIS
The primary outcome measure was death in hospital. Data collected were subjected to multivariate analy-
Emergency
Immediate life-saving operation, resuscitation simultaneous with surgical treatment. Operation usually within 1 h

Urgent
Operation as soon as possible after resuscitation. Operation within 24 h

Scheduled
An early operation, but not immediately life saving. Operation usually within 3 weeks

Elective
Operation at a time to suit both patient and surgeon

sis to determine those factors that predicted survival or death. In addition to this, we identified those factors that best explained anaesthetic and surgical opinions, before and after operation, of survival. A subsidiary analysis was also performed to determine the factors that explained the use of invasive cardiovascular monitoring. All the analyses were performed using the LOGIST procedure in SAS version 6.08 for Windows.

All the outcomes in this study were binary and were modelled using multiple logistic regression. This is a standard statistical procedure that determines the best possible explanation of a binary outcome in terms of the concerted effects of several potential variables (explanators) offered to the model. No assumptions are made about the distribution of the potential explanators. For all the models in this study a stepwise method of variable selection was used. This means that potential explanatory variables are added in turn to the model, starting with the variable with the most significant effect.

Date .......................... Patient name ........................................... Consultant .............................
Reg. number .......................... Age .......................... Ward ..........................
Time ................... 08:00–17:59/18:00–24:00/00:01–07:59

PREOPERATIVE ASSESSMENT
Indication .......................... Grade of surgeon ..........................
Grade of anaesthetist .......................... Immediate preop ASA ..........................

Do you think the patient will leave hospital alive?  Yes/No
Does the surgeon?  Yes/No
Was the patient adequately resuscitated preoperatively?  Yes/No

PREOPERATIVE RISK FACTORS
Poor general condition  Y/N
Dehydration/hypovolaemia  Y/N
Electrolyte disturbance  Y/N
(Anaemia (Hb<10)  Y/N
Malnutrition  Y/N
Marked obesity  Y/N
Septicaemia  Y/N
Diabetes  Y/N
Dementia or confusion  Y/N

Hypertension  Y/N
Heart failure  Y/N
Valvular disease  Y/N
IHD  Y/N
Non-sinus ECG  Y/N
Other significant ECG abnormality  Y/N
(Against state .......................... )
Acute respiratory disease  Y/N
Chronic respiratory disease  Y/N
Raised creatinine or urea  Y/N
Acute renal failure  Y/N

Too sick for above to be determined  Y/N
Other (state .......................... )

ANAESTHETIC MANAGEMENT
GA/FA + extradural  Y/N
Invasive monitoring (IABP/CVP/PAWP)

POSTOPERATIVE MANAGEMENT
Operation performed .......................... Duration ..........................

Did the patient spend enough time in recovery?  Y/N
Was the patient sent to ICU?  Y/N
Would you have sent the patient to ICU but ICU full?  Y/N
Do you think the patient will leave hospital alive?  Y/N
Does the surgeon?  Y/N

Figure 1  NCEPOD Classification of urgency of operation.

Figure 2  Questionnaire used in the study.
After a variable is added to the model, the model is reviewed so that any redundant variables are removed. The modelling process is stopped when there are no more significant explanatory variables. The resulting model can be used to calculate a predicted probability that a particular patient will be in a particular outcome group (equation 1). Significance levels of $P < 0.05$ and $P < 0.1$ were used as indicated.

$$P = \frac{e^{b_0 + b_1 V_1 + b_2 V_2 + b_3 V_3 + \ldots}}{1 + e^{b_0 + b_1 V_1 + b_2 V_2 + b_3 V_3 + \ldots}}$$

Where $\log it \ p = b_0 + b_1 V_1 + b_2 V_2 + b_3 V_3 + \ldots$, where $b_0$ is the model intercept, $b_1$, $b_2$, are the parameter estimates for variables $V_1$, $V_2$ and $P$ is probability of survival.

Results

Data were collected from 107 patients, of whom 47 died. The age range was 65–97 yr. Patient characteristics and univariate analysis data are presented in tables 1–3.

The multiple logistic regression modelling death, when the opinions of the medical staff were not used in the model, had five factors that were significant at $P < 0.05$. The parameter estimates are shown (table 4); a negative parameter estimate increases the estimated probability that the patient will die. For example, women have an increased probability of death (the parameter estimate is $1.57$). The estimated probability of death increases with increasing age and increasing ASA class. Admission to the ICU and use of invasive monitoring are also associated with increased mortality.

The area under the receiver operating characteristic curve for this model has an area of 0.93 (SD 0.02) (fig. 4). This suggests that 93% of the variability in mortality is explained by the five explanatory variables in this model.

If the criterion for variable selection is relaxed (to $P < 0.1$) then other variables are included in the model: an SHO anaesthetist decreases the risk of dying ($P = 0.07$) and if the senior surgeon present is a consultant the estimated probability of dying increases. If the opinions about survival recorded by the surgeon and the anaesthetist before and after operation are offered as potential factors, the opinion of the anaesthetist after operation is a significant factor explaining outcome ($P = 0.02$). If only the opinions given before surgery are offered as potential explainers, then neither that of the surgeon nor the anaesthetist is selected as significant at $P < 0.1$.

Six factors were significantly associated with the anaesthetist predicting, before the operation, that the

| Table 2 Patient management. *ICU full for five patients. **Five patients died in theatre; in nine cases ICU was full. ns = not stated |
|---|---|
| Survivors | Deaths |
| N | 60 | 47 |
| Anaesthetist | | |
| Consultant/senior registrar | 35 | 21 |
| Registrar | 11 | 12 |
| SHO | 10 | 7 |
| Staff grade | 4 | 7 |
| Not stated | 0 | 0 |
| Surgeon | | |
| Consultant/senior registrar | 39 | 20 |
| Registrar | 14 | 22 |
| SHO | 3 | 0 |
| Staff grade | 4 | 4 |
| Not stated | 0 | 1 |
| General extradural and anaesthetic | 33 | 22 |
| Invasive monitoring | 18 | 39 |
| Operation performed | | |
| Bowel resection | 15 | 18 |
| No resection | 24 | 12 |
| AAA | 3 | 5 |
| Not stated | 18 | 12 |
| Duration of operation | | |
| < 2 h | 31 | 20 |
| 2–3 h | 20 | 15 |
| > 3 h | 5 | 11 |
| Not stated | 4 | 1 |
| Transferred to ICU after operation | 6* | 21** |
| Correct opinions before operation | | |
| Anaesthetist | 52 (3ns) | 32 (1ns) |
| Surgeon | 50 (4ns) | 18 (2ns) |
| Correct opinions after operation | | |
| Anaesthetist | 52 (0ns) | 34 (3ns) |
| Surgeon | 52 (1ns) | 28 (2ns) |

Figure 3 American Society of Anaesthesiology (ASA) classification of physical status (abridged).
patient would die ($P < 0.1$, table 6). In the opinion of the anaesthetist the probability of the patient dying was increased when the patient was in a ‘poor condition’, had sepsis or had undergone bowel resection. The probability increased with increasing patient age and ASA class. If the anaesthetic technique included extradural anaesthesia in addition to general anaesthesia, the estimated probability decreased. Three factors (ASA status, age and poor condition) were common to the models of anaesthetic opinion both before and after operation.

Six factors were significant explanators ($P < 0.1$) of whether or not invasive monitoring was used (table 7). The probability of invasive monitoring being used was reduced if the senior surgeon was a senior registrar or the senior anaesthetist was a consultant. The probability was increased if the senior surgeon was a consultant, the patient was in ‘poor condition’, if the patient was admitted to ICU after the operation or if a consultant anaesthetist was involved in the decision to operate.

Table 8 illustrates how the model might be used to ascribe a probability of death to individual patients. This is included to illustrate the model, but validation is necessary before such use of the model can be recommended.
Discussion

Several of the factors recorded before operation are subjective (such as poor condition, adequate resuscitation). These terms were used to allow for individual assessment of factors not detected by lists of pathophysiological factors. This practical approach to detecting factors that may influence overall assessment or treatment of patients is similar to that used by other investigators, and is supported by the findings of the Riyadh Intensive Care group.9

We confirmed that patients aged over 65 yr undergoing urgent or emergency surgery have a high risk of dying. We found that 44% of these patients died without leaving hospital. No patient of ASA class IV or V and aged over 85 yr survived. The factors significantly associated with death in this study are consistent with other studies.10,11 Age and ASA status were factors in models of mortality and of the anaesthetist’s opinion, both before and after operation, regarding the chance of survival. Neither factor was a significant explainer of the use of invasive monitoring. Individual risk factors in the anaesthetic assessment, and a risk factor score that summed these factors, did not predict outcome.

Is age itself a risk factor for surgery? Mortality after surgery undoubtedly increases with age12 but this could be because of the increased prevalence of medical conditions.3 We found greater age to be associated with a greater likelihood of death irrespective of co-morbidity.

There has been debate about the predictive ability of the ASA classification since its first description.13–15 Patients in the higher ASA classes have higher risk of dying,11 but some argue that ASA status, on its own, cannot usefully discriminate between outcome groups because it does not take operative factors into consideration.11,12 In the present study all patients had similar major surgery and the ASA status helped predict the likelihood of death, confirming the value of this semi-subjective tool.15

We found that women had a greater probability of dying. There are several possible explanations for this: women may have a higher incidence of co-morbidities such as cardiac or respiratory problems; women may present at a later stage of illness and thus be more unwell before they receive treatment; or the diseases that lead to laparotomy may differ in women compared with men. This pilot study cannot differentiate between these possible explanations but it highlights an area for future research. A previous study of surgical gastrointestinal emergencies found that women responded less well to resuscitation efforts than men.12 Failure to respond to resuscitation was associated with increased mortality and morbidity.

The estimated probability of death was increased in patients who were admitted to the ICU or who had invasive haemodynamic monitoring (no deaths were caused by complications of invasive monitoring). Initially this might seem to be counter-intuitive, but it could reflect appropriate use of both these interventions. Those patients that are most sick are admitted to the ICU and have invasive monitoring started in theatre. This illustrates that although a significant explainer of an outcome, in this case death, does not necessarily influence outcome, it may be a marker of something else that influences the outcome. This is important because our data should not be interpreted as implying that reducing invasive monitoring would improve outcome.

The model of the anaesthetist’s opinion, before operation, of the likelihood of survival had only two factors in common with the model of actual mortality: age and ASA status. Of the other significant factors, ‘poor condition’ and ‘adequate resuscitation’ might be expected to be selected, because they are subjective terms and are thus likely to correlate well with the anaesthetist’s opinion of whether the patient will survive. The grade of surgeon and anaesthetist tends to be similar for any given operation. Thus ‘registrar surgeon’ as a significant explainer of the anaesthetist’s opinion of the likely outcome may reflect anaesthetists’ opinion that the patient is more likely to die if the surgeon is a registrar; alternatively the registrar anaesthetists who work with registrar surgeons may be generally more pessimistic about patient survival. The finding that the absence of bowel obstruction is an explainer of anaesthetist’s preoperative opinion may represent a belief that patients with bowel perforation or abdominal aneurysm have a higher mortality than patients with obstruction. However we found no significant difference in outcome between these groups with univariate or multivariate analysis.

The model of the anaesthetist’s opinion, after operation, of survival had three variables in common with the model before operation (age, ASA status and poor condition). Of the other factors associated with anaesthetic prediction, after operation, of death, two factors were available before operation (presence of sepsis and the absence of a consultant anaesthetist) and two were not (bowel resection and the absence of extradural anaesthesia). The anaesthetist was more likely to believe the patient would survive when extradural anaesthesia was used. This may be because the most sick patients were too unstable or urgent to permit use of extradural anaesthesia or because anaesthetists using extradural anaesthesia believe it reduces risk. If the senior anaesthetist was a consultant then the estimated probability of death decreased. This may be because consultants treated fitter patients than other anaesthetists or consultants may be more optimistic; we could not differentiate between these two possibilities.

Invasive monitoring was a significant explainer of mortality, and we used the model of whether invasive monitoring was undertaken to study this feature. If a consultant anaesthetist was involved in the decision to operate it was more likely that invasive monitoring was used. However, if a consultant anaesthetist was involved in treatment, the use of invasive monitoring was less likely. Consultant anaesthetists asked for their opinion may err on the side of caution and suggest the use of invasive monitoring, but when treating a patient may judge that some patients do not require it. Admission to the ICU was associated with the use of invasive monitoring and this may partly account for the greater use of invasive monitoring when a consultant was involved in the decision to operate. The grade of the senior surgeon also had an effect: invasive monitoring was more likely when the senior surgeon was a consultant and less likely when he or she was a senior registrar.
We have identified several factors that could be used to predict mortality in patients aged over 65 yr undergoing urgent or emergency laparotomy. These factors are easily determined and do not require complex investigation. Before the widespread use of a model using these findings can be recommended the model must be validated to establish that it can be generalized. The factors associated with survival and those associated with the anaesthetist’s opinions about survival differ. Greater age and ASA class are explanators of survival in this group of patients and also explanators of anaesthetist’s opinions about survival. This implies that anaesthetists correctly include these factors when assessing patient risk. However anaesthetist’s opinions are associated with some factors that do not predict outcome and not associated with some that do. As opinions about survival are likely to influence postoperative management of these high-risk patients, further development of an objective tool to determine risk might be useful. The goal of applying such a model to individual patients remains a long way off.

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References