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# Preventing surgical deaths: critical care and intensive care outreach services in the postoperative period

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The last 200 years have seen enormous improvements in the management of patients undergoing surgery. This has been in part because of key discoveries such as anaesthesia, asepsis, antibiotics and X-rays, to name but a few. There have also been important organizational changes, including the development of postoperative recovery rooms and critical care, that have made important contributions to postoperative safety. Surgical mortality has fallen while the range and invasiveness of surgical procedures have expanded. Operations are undertaken on patients who would have formerly been deemed unsuitable because of serious comorbidity, age or physiological derangement. Surgery is not without its risks. Deaths directly attributable to anaesthesia are extremely rare. However, anaesthetic management and postoperative care are important in preventing surgical deaths. There will undoubtedly be further discoveries that will benefit patients having surgery. There is good evidence that a greater provision of critical care support can save lives now.

Henry VIII of England was instrumental in bringing about the union of surgeons and barbers in 1540.[57] In 1745 the surgeons split from the barbers to form the Company of Surgeons that evolved into the Royal College of Surgeons of England. By the middle of the nineteenth century surgery was an established and well-respected profession. Much surgery was low risk. However, more serious operations such as amputation were associated with a high mortality. On October 16, 1846, at approximately 10:15 a.m. in the Massachusetts General Hospital, William Thomas Green Morton administered ether anaesthesia so that Dr John Collins Warren could remove a vascular malformation from the neck of Edward Gilbert Abbott. Although this extraordinary discovery was fundamental to the development of surgery, many other innovations were also necessary to allow surgeons to operate safely for prolonged periods, and within the abdomen, chest and head as well as on the body surface.

As long ago as 1801 a room at the Newcastle Infirmary was reserved for patients who were dangerously ill or had recently undergone a major operation.[25 71] In 1859, Florence Nightingale mentioned the concept of a space within the hospital dedicated to caring for postoperative patients.[25] A recovery room was in use at the Massachusetts General Hospital by 1873, and Burdett, writing in 1893, mentioned the provision of recovery rooms.[71] In the UK, recovery rooms were not routinely included in hospital planning guidelines in the period immediately following the Second World War.[71] As late as 1964, an editorial in the journal *Anaesthesia* drew attention to the 'most fantastic difference in standards' that existed between hospitals in their provision of care for surgical patients.[24]

Expertise in caring for critically ill patients has developed rapidly over the last 50 years. High-dependency areas were set up for selected groups of patients, such as the postoperative neurosurgical unit at the Johns Hopkins Hospital in 1923[11] and a preterm baby care centre in Chicago in 1927.[60] It is generally acknowledged that intensive care, at least in Europe, began with the polio epidemic in Copenhagen, Denmark, in 1952.[41] The overwhelming number of patients who required respiratory support meant that negative-pressure cuirass ventilators (iron lungs) were not available for all. In desperation, tubes were placed into the tracheas of the paralysed polio victims and medical students were employed to squeeze bags to ventilate the patients. This means of support was much better than the older method. A randomized control study was unnecessary, as there was a mortality of less than 50% for positive-pressure student ventilation compared with 80% with the cuirass ventilator. This experience encouraged the development of equipment and facilities for looking after critically ill patients. The first successful dialysis machine was developed by Willem Kolff in the early 1940s,[11] and Paul Zoll unveiled the first external defibrillator in 1956.[58] Kouivenhoven introduced external cardiac massage in 1960.[58] By 1958, about 25% of the largest community hospitals in the USA had at least one intensive care unit (ICU). In the 1960s, coronary care units (CCUs) were introduced and were shown to contribute to a reduction in mortality of about 20%.[43] ICUs became more common and high-dependency units (HDUs) also became established. More recently, in the UK, the needs of critical care patients have been categorized. Level 3 patients usually require ICU support, and Level 2 patients require HDU support.[37] Many units are now designated as critical care units (CrCUs), able to provide combined Level 3 and Level 2 support.

Surgical mortality is approximately 0.8–1% for all patients undergoing surgery.[49] Mortality directly attributable to anaesthesia is probably in the region of 1 in 50 000 anaesthetics,[38] although anaesthesia and the anaesthetist undoubtedly contribute to other deaths. There are approximately 3 million operations per year in England.[19] Although overall mortality is low, this still accounts for some 30 000 postoperative deaths per year in the UK. The majority of these deaths occur on hospital wards, 5 days or more after surgery.[34]

## Recognizing high-risk surgical patients

In order to provide appropriate perioperative support to high-risk surgical patients, steps must be taken to identify them. High-risk surgical patients can be identified preoperatively, intraoperatively or postoperatively.

### *Preoperative identification*

In 1988, Shoemaker and colleagues[59] listed a subjective assortment of criteria related to the patient or procedure which were associated with a postoperative mortality of 33%. More recently, similar criteria were associated with a 17% mortality.[70] Evidence suggests that patient outcome is associated with several factors including the procedure to be undertaken, the physiological reserve of the patient, chronic health problems and physiological derangements. Age may be a proxy for physiological reserve and at its extremes is clearly associated with increased mortality.

Scoring systems can be used to quantify the risk. Even simple, subjective measures such as the ASA score can be used to stratify patients by surgical risk.[16,51] Approximately 50% of surgical deaths are in patients scoring ASA IV or V. Although percentage mortality is considerably less for patients with lower ASA scores, because more operations are performed on these patients they account for many of the deaths. About 33% of those who die are assessed as ASA III, and 17% score ASA I or II.[10] More objective assessment systems have been developed, such as the Goldman cardiac risk index[33] and anaerobic threshold testing.[48] A recently published score, the Surgical Mortality Score, is based on the odds ratio derived from multiple logistic regression of information that is readily available before surgery.[35] This includes the surgical speciality, patient age and sex, whether the surgery is elective or emergency, the time that surgery is scheduled to start and the median operating time obtained from an independent database. Over 11 000 patients from one institution were used to develop this model. Patients with scores >17 (76.3% of patients) had an overall

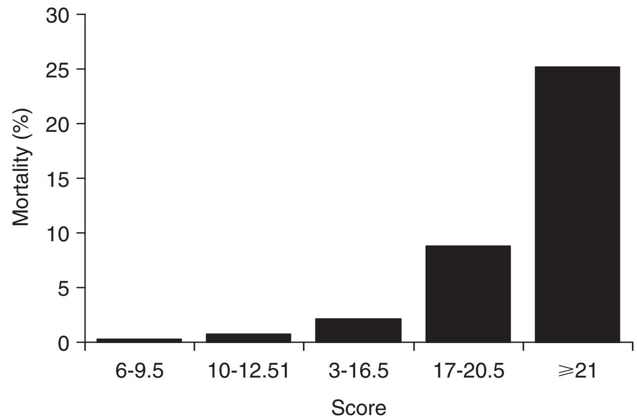


**Fig 1** The Surgical Mortality Score: hospital mortality versus score.

associated hospital mortality of 1.3%. Scores of 17–20.5 (18.8% of patients) were associated with an 8.8% mortality, and scores ⩾21 (4.9% of patients) had a mortality of 25.1% (Fig. 1). Although further work is required to see whether this model is generalizable to other hospitals and groups of patients, it does indicate some of the factors that appear to be relevant when predicting surgical mortality. It may provide a simple audit tool that could be used to estimate the number of critical care beds for a hospital's surgical population.

### *Intraoperative identification*

The high-risk surgical patient may not declare himself until the procedure is underway. Obvious examples are anaesthetic or surgical misadventure such as aspiration, anaphylaxis, uncontrolled haemorrhage or accidental intestinal perforation. POSSUM is a widely used scoring system for non-cardiac surgical patients.[14] Although many of the factors required are available preoperatively, intraoperative events such as blood loss are required to predict morbidity and mortality. It should be noted that the original POSSUM model has been refined on the basis of further data.[53,68] Scoring systems such as this should not be used to predict outcome for an individual, but may be useful when comparing populations, such as between hospitals. Outcome can be related to physiological measurements taken at the end of surgery. This suggests that attention to preoperative preparation and intraoperative events may be key to improving surgical mortality.[47]

### *Postoperative identification*

A study of 3075 consecutive patients admitted to a surgical ward at the University Hospital, Utrecht, The Netherlands, over a period of 1 year investigated the determinants of serious complications.[66] One or more serious complications, defined as grades 5–7 according to the Clavien classification,[13] occurred in 12% of patients. The factors which best predicted these complications included age, ASA physical status, smoking, defined chronic disease, emergency or urgent surgery and whether surgery was major and/or involved the chest or abdomen. Physiological values are one extremely important way of identifying high-risk patients. Abnormal values of blood pressure and heart rate recorded in the postoperative recovery area are sensitive enough to identify patients with an increased risk of unplanned critical care admission or death.[56] Patients with poor surgical outcomes are usually identifiable early in the postoperative period. Out of >2000 consecutive surgical patients reported by Gamil and Fanning,[26] 5% had serious and potentially life-threatening events in the 24 h immediately following surgery. Deterioration within the 24 h following surgery was apparent in 23 of 29 patients who died or suffered serious disability. The authors considered that the outcome might have been better for many of these patients if their initial deterioration had been prevented or managed more aggressively. In another study of 115 patients undergoing elective oesophageal surgery, all patients who died had an oxygen delivery >445 ml $min^{-1}$ $m^{-2}$ 6 h postoperatively.[40] Oxygen delivery was also significantly lower in those who developed an anastomotic leak or severe pneumonia.

## The critical care gap

Between 1988 and 2001, the total number of hospital beds in England fell by 37% to 186 000. Over the same period the number of acute beds fell by 15%. This was while the population continued to expand and expectations about the achievements of health care grew.[61] Compared with other West European countries the UK has historically spent less per capita on health, and less on technology and advanced medical procedures,[55] and the percentage of hospital beds given over to critical care has been low (Fig. 2).[23] Since 1999, there has been an overall 40% increase in total critical care beds in England, consisting of 16% more ICU beds and 91% more HDU beds. In January 2004 there were a total of 1769 Level 3 critical care beds in England, of which 380 were specialized. There were also 1374 Level 2 beds, of which 452 were specialized. Despite this increase, only 2.1% of acute hospital beds are non-specialized critical care beds (Levels 2 and 3). This equates to approximately 0.6 critical care beds per 10 000 population in England, compared with 4.4 per 10 000 in the USA.[6] There is a critical care gap in British hospitals. This is where patients languish who require a higher level of care than can be provided on the ward, but who are unable to be admitted to a critical care area because of lack of beds. This gap may have increased and become more hazardous over recent years as medical training has become shorter, nursing training has become more academic, hours of work have decreased, affecting continuity of care, and increasing specialization has taken senior doctors off the ward into the endoscopy suites and catheter laboratories.

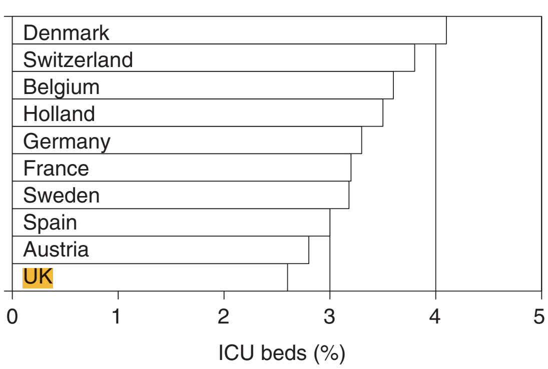


**Fig 2** ICU beds as a percentage of total hospital beds (1999 data).

## Preventing surgical deaths

A team approach and attention to detail can be very effective in decreasing mortality in high-risk surgical procedures such as oesophagectomy.[69] There is evidence to suggest that many British surgical patients could benefit from access to a critical care area but are denied it.[6 64] Many years ago, Rao and colleagues[54] demonstrated the importance of aggressive intervention to maintain cardiorespiratory goals in order to prevent reinfarction in surgical patients with a recent heart attack. A considerable number of papers supporting the benefit of perioperative optimization of patients undergoing major elective surgery have now been published.[5 39] Many of these papers have shown a clinically relevant and statistically significant improvement in outcome in the patients in the intervention arm of the study. Although much of the focus has been on the importance of fluid administration and the optimization of oxygen delivery and consumption, it is necessary to stress that the package of care has involved critical care support. Reports by the National Confidential Enquiry into Perioperative Deaths (NCEPOD) show that the majority of postoperative deaths in the UK occur more than 5 days after surgery. In the NCEPOD report published in 2001,[34] only 5% of 1606 deaths were in the theatre/recovery areas. Postoperatively, 40% of those who died went to an ICU or HDU. A further 16% went to the ward even though it was judged that ICU or HDU admission was desirable, but it was not requested or was unavailable. Successive NCEPOD reports have emphasized the need for ICU and HDU facilities to be made available. The 2001 report[34] stated: 'It is difficult to understand why some hospitals deny HDU facilities to selected patient groups'. The same report also refers to intensive care outreach saying: '...guidelines to determine which patients should be referred to the critical care team should be developed...'.

## Intensive care outreach services (ICORS)

Intensive care outreach services (ICORS) were introduced throughout much of the UK in the latter half of 2000 and early 2001. The Audit Commission's report *Critical to Success*, published in 1999, first used the term 'outreach' in this context.[1] 'Highest priority recommendations' included agreeing 'danger signs' to help identify patients at risk of deteriorating. *Comprehensive Critical Care*, a

Department of Health Report published in 2000, further developed the concept of outreach.[18] The critical care service was given responsibility for critically ill patients throughout the hospital, not just in the ICU. This is often associated with the phrase 'critical care without walls'. Most importantly, the resources to fund these services were provided. At this time there was good evidence to demonstrate that there was a problem with critically ill patients on the ward, but there was limited evidence to show that ICORS were the best solution.

The UK Intensive Care Society has suggested a fivefold role for ICORS:[36]

(1) to avert admissions to critical care;
(2) to facilitate timely admission to critical care and discharge back to the ward;
(3) to share critical care skills and expertise through an educational partnership;
(4) to promote continuity of care;
(5) to ensure thorough audit and evaluation of outreach services.

## *Background*

ICORS grew out of a recognition that there are many patients on acute hospital wards who are, or who are at risk of becoming, critically ill. Patients who are suboptimally managed in hospital prior to ICU admission have an increased mortality.[44 45] In addition, the longer patients are in hospital before ICU admission, the higher is their mortality.[30] Patients on the ward for up to 3 days before ICU admission have a hospital mortality of 47.1% (standardized mortality ratio 1.09). This increases to 67.2% hospital mortality (standardized mortality ratio 1.39) for patients on the ward for more than 15 days before ICU admission. Ward patients are not only of concern prior to ICU admission; over a quarter of all patients who die despite ICU admission do so after discharge back to the ward from the ICU, and this includes many of the surgical deaths.[31] Pressure to provide ICU beds for new admissions exposes patients in the ICU to the risks of early discharge back to the ward.[17 27] Patients admitted to the ICU from the ward are in hospital and are therefore accessible, and there is an opportunity to intervene to prevent an adverse outcome.

Hillman and colleagues[42] pioneered Medical Emergency Teams (METs) in Australia with call-out criteria based upon markedly abnormal physiological values. Introduction of METs has been shown to reduce arrests on the ward and decrease mortality.[3 9] They have also been shown to improve the outcome of patients undergoing major surgery.[4] This study reported 336 adverse outcomes in 190 patients before the introduction of the MET. The number decreased to 136 in 105 patients during the intervention period. These improvements were due to decreases in the incidence of respiratory failure, strokes and acute renal failure. There was also a decrease in emergency ICU admissions and the number of postoperative deaths.

ICORS are a development of these teams, but they generally have a wider remit. We piloted an ICORS at the Royal London Hospital in 1997.[32] This showed that there were significant numbers of critically ill patients on the ward. When our ICORS was aware of the seriously ill ward patients, arrests were prevented. More recently, in an Australian hospital, a critical care nurse reviewed high-risk surgical patients for the first three postoperative days.[62] Because of funding limitations, the nurse was not available at the weekends. The patients underwent major vascular, orthopaedic or colorectal surgery. Predefined serious adverse events were recorded as well as 30 day mortality. There was an initial 5.5 month surveillance phase of 319 patients. This was followed by a further 7.5 months surveillance of 345 patients where intervention was also allowed. In the intervention phase, the nurse suggested or initiated patient care strategies including oxygen therapy, aggressive fluid management, patient education on physiotherapy and analgesia, staff education or calling the acute pain team, the MET or other doctors. In both phases, about 14% of patients had serious adverse events. Approximately one intervention per patient was made and this was associated with a decrease in the incidence of serious adverse events from 23 to 18 per 100 patients. The only serious adverse event with an increased incidence during the intervention phase was acute myocardial infarction at 4 per 100 patients before intervention increasing to 7 per 100 during intervention. The authors suggest that this may have been due to improved detection because of increased surveillance. If myocardial infarction is excluded and only the 10 other serious adverse events are considered, there was a fall in adverse events from 19 to 11 per 100 patients during the intervention period. Mortality during the 30 days following surgery was 9% during surveillance and 7% during intervention (not significant). This study shows that serious adverse events are common in high-risk patients during the days following surgery. It also suggests that early detection and intervention may be beneficial.

The composition of ICORS varies between hospitals depending on the resources available.[20] At their most basic they consist of a single nurse providing an education programme on the identification and appropriate management of the critically ill, while in some hospitals they are composed of a multidisciplinary team providing a 24 h service with regular medical input by senior intensive care clinicians. The majority of teams are nurse led. Where possible, they not only intervene to expedite ICU admission for the critically ill, but also monitor discharged ICU and HDU patients and supervise the use of more invasive therapies and monitoring, such as continuous positive airway pressure (CPAP), inotropic support drugs and central venous pressure lines.

## *Early warning scores*

Physiologically based early warning scores (EWSs) provide staff with a way of identifying and monitoring the critically

**Table 1** The PAR early warning score. CNS: A, alert; C, confused; V, responds to voice; P, responds to pain; U, unresponsive. Urine: urinary output or dialysis

| Score | 3 | 2 | 1 | 0 | 1 | 2 | 3 |
|---|---|---|---|---|---|---|---|
| Temperature (°C) | | <35.0 | 35.0–35.9 | 36.0–37.4 | 37.5–38.4 | ⩾38.5 | |
| Heart rate (beats $min^{-1}$) | <40 | | 40–49 | 50–99 | 100–114 | 115–129 | ⩾130 |
| Systolic blood pressure (mm Hg) | <70 | 70–79 | 80–99 | 100–179 | | ⩾180 | |
| Ventilatory frequency (breaths $min^{-1}$) | | <10 | | 10–19 | 20–29 | 30–39 | ⩾40 |
| $Sp_{O_2}$ (%) | <85 | 85–89 | 90–94 | ⩾95 | | | |
| CNS | | | | A | C | V | P or U |
| Urine (ml $kg^{-1}$ $h^{-1}$) | Nil | <0.5 | Dialysis | 0.5–3 | >3 | | |

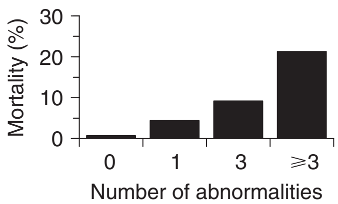


**Fig 3** Number of physiological abnormalities and 30 day hospital mortality.

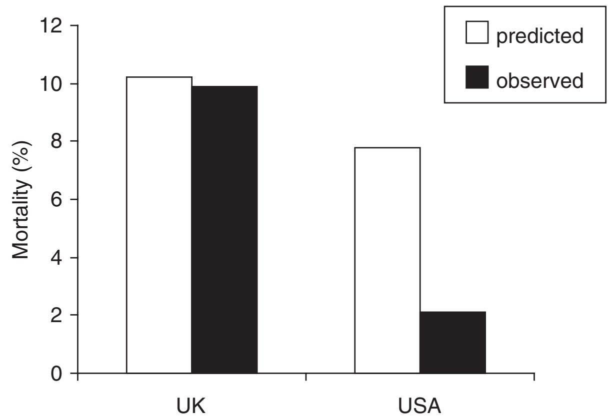


**Fig 4** Observed and predicted mortality for surgical patients in the UK and USA.

ill.[28] There are many different formats but they follow a similar theme, awarding points for varying degrees of abnormality of different physiological systems. The higher the total score, the more 'at risk' is the patient. The EWS used at the Royal London Hospital (PAR score) is shown in Table 1.

To date EWSs have been devised using clinical acumen and common sense. They have yet to be scientifically validated as predictors of preventable adverse outcomes. The score generated depends crucially on the definition of normal physiological values and how much importance the score's creators have attached to the abnormality of each of the physiological variables measured.

Using the definition of normality from the PAR score, a hospital-wide point prevalence study showed that the number of abnormal physiological measurements is strongly associated with 30 day hospital mortality (Fig. 3).[29] As part of the same study, we found that patients who were cared for in a ward area that was judged inadequate for their needs had an increased mortality. The ICORS at the Royal London Hospital sees all patients discharged from the ICU and the surgical HDU, as well as primary referrals to patients on the ward. Approximately 70% of the ICORS assessments are on patients cared for by the surgical services. Patients are in hospital for a median of 10 days before being seen; overall mortality is about 15%, with patients dying after about 30 days in hospital. Evidence is emerging that ICORS improves survival of patients discharged from ICU and may reduce the number of readmissions.[2] There is also evidence showing that in-hospital mortality is lower in wards where ICORS operates than in those where it does not.[52]

In summary, ICORS are a link between the ward and the critical care service. They are primarily an attempt to compensate for the relative lack of critical care beds. However, they perform a valuable function in propagating critical care wisdom and skills throughout the hospital, raising awareness of the needs of the critically ill and encouraging their early recognition. The introduction of the Hospital at Night model[21] is likely to increase the burden and responsibility of outreach services.

## Critical care and surgical patients

The leapfrog group[63] is a group of Fortune 500 companies in the USA representing approximately 34 million health care consumers. They have made a limited number of recommendations based on published evidence. As they are committed to using only facilities that fulfil these requirements, there is a strong incentive for health care organizations to comply. This group states that '. . . the hospital where surgery is performed can mean the difference between life and death'. This is based upon the evidence for some operations showing an association between mortality and the number of procedures undertaken.[7 12 22 65] There is also some evidence that specialist training and the volume of individual surgeons affects outcome. Another recommendation was based on the evidence that 'intensivists' improve outcome for critically ill patients. Those with expertise in caring for the critically ill have skills, knowledge and expertise that make a difference.[8 15 46 50 67]

A recent study has compared mortality for patients undergoing major non-cardiac surgery in the UK and in the USA (Fig. 4).[6] P-POSSUM was used to predict outcome. In the

UK predicted mortality was 10.2% and observed mortality was 9.9%. However, in the USA predicted mortality was 7.8% and observed mortality was just 2.1%. When explaining the difference in outcome, the authors thought that the provision of critical care services might be important. They stated that the UK has 8.6 critical care beds per 100 000 population whereas the USA has 30.5. The proportion of hospital budget spent on critical care is 1–3% in the UK and 20–34% in the USA. This paper is not without its limitations, but if this explanation is to be ignored an alternative convincing theory is required.

## Conclusions

Preventing surgical mortality is about providing a package of care. This includes appropriate optimization preoperatively and excellent intraoperative surgical and anaesthetic management, but also postoperative support. Elements of care include fluids and judicious use of blood products, management of cardiac output and blood pressure, control of temperature, provision of good analgesia, nutrition and respiratory support. Admission to a critical care area allows close monitoring and early intervention if problems arise. Many surgical deaths occur several days after an operation. Therefore there is opportunity to intervene. Physiological abnormalities are an important way of identifying high-risk patients. Critical care outreach services have a role in bridging the critical care gap that exists between the ward and the ICU or HDU. Critical care support and intervention prevent deaths. There is no substitute for an adequate number of critical care beds to which appropriate surgical patients can be admitted.

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