Identifying Priorities in Intensive Care : a description of a system for collecting intensive care data, an analysis of the data collected, a critique of aspects of severity scoring systems used to compare intensive care outcome, identification of priorities in intensive care and proposals to improve outcome for intensive care patients.

Goldhill, David Raymond

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Dr David Raymond Goldhill

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1. Abstract

Identifying Priorities in Intensive Care

This thesis reviews the requirements for intensive care audit data and describes the development of ICARUS (Intensive Care Audit and Resource Utilisation System), a system to collect and analyse intensive care audit information. By the end of 1998 ICARUS contained information on over 45,000 intensive care admissions. A study was performed to determine the accuracy of the data collection and entry in ICARUS. The data in ICARUS was used to investigate some limitations of the APACHE II severity scoring system. The studies examined the effect of changes in physiological values and post-intensive care deaths, and the effect of casemix adjustment on mortality predicted by APACHE II. A hypothesis is presented that excess intensive care mortality in the United Kingdom may be concealed by intensive care mortality prediction models. A critical analysis of ICARUS data was undertaken to identify patient groups most likely to benefit from intensive care.

This analysis revealed a high mortality in critically ill patients admitted from the wards to the intensive care unit. To help identify critically ill ward patients, the physiological values and procedures in the 24 hours before intensive care admission from the ward were recorded: examination of the results suggested that management of these patients could be improved. This led to the setting up of a patient at risk team (PART). Two studies report the effect of the PART on patients on the wards and on the patients admitted from the wards to the intensive care unit. Additional care for surgical patients on the wards is suggested as a way of improving the management of high-risk postoperative patients. The thesis concludes by discussing the benefits of the ICARUS system and speculating on the direction that should be taken for intensive care audit in the future.

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2. Introduction

Ethics Committee permission was obtained for the studies reported.

In 1989 The London Hospital intensive care unit (ICU) (now The Royal London Hospital) was admitting approximately 1000 patients per year. Rudimentary hand-written information was the only easily accessible data on these admissions. Analysis of this data was laborious, inaccurate and difficult to perform. Basic information such as the age and sex distribution of the patients, average ICU stay, whether patients survived ICU and the number of re-admissions to ICU was unavailable.

Intensive care is a scarce and expensive resource which needs to be used appropriately (Atkinson S et al. 1994, Bion J. 1995a). Alternatives to intensive care, such as high dependency care or support on the ward, may be suitable for some critically ill patients (Metcalfe A. 1995, Kilpatrick A et al. 1994) but neither of these alternatives nor intensive care have been evaluated adequately. Intensive care involves recurring costs of approximately £75,000,000 per annum in North Thames (1997 figures) for a group of patients with high mortality (approximately 25%) and high morbidity. Evaluation of intensive care practice is essential to inform risk management decisions, for quality assurance purposes and to ensure appropriate treatment is available for those who will benefit.

Performance comparison between ICUs is impossible without an agreed dataset which is accurately collected and takes account of the wide ranging differences in case mix between ICUs. In 1990 ICU audit was started at the Royal London Hospital and this

was extended to most ICUs in North East Thames in 1992 and then again in 1995 to some of the ICUs in the North Thames region. By 1996 24 ICUs were participating and had contributed data on over 30,000 ICU admissions. These data are used as the basis for regional ICU audit meetings, and provide information for analysing ICU performance. This audit system was given the name **ICARUS** (Intensive Care Audit and Resource Utilisation System).

Collecting intensive care data

Clinical audit has been described as a "feedback loop" consisting of data collection, audit, standard setting, change of practice and then re-audit to evaluate the effects of the change. However nothing can be determined without accurate data collection and analysis. This is possibly the most difficult part of the cycle. The King's Fund report on Intensive Care (Report of the Kings's Fund panel. 1989) stated "There is an urgent need for intensivists to agree what data (clinical and economic) should be collected by every ICU to allow proper audit. Especially important is the need for prospective research to evaluate certain specific practices in intensive care". In 1990 the Intensive Care Society published a minimum data set to be collected for all patients receiving intensive care (Intensive Care Society. 1990). This data set includes demographic information, disease classification, and outcome. Also included is the ability to score patients' severity of illness according to the APACHE II system (Knaus WA et al. 1985), with the intention that this would allow comparisons to be made within and between national and international intensive care units.

For the objectives of the King's Fund and the Intensive Care Society to be realised a nationally agreed data set must be collected. Ideally this data should be collected and

processed locally before transmission to a central data collection point for analysis. However in 1990 few ICUs in the United Kingdom had the necessary resources, both technical and human, to accomplish this in a uniform and standardised manner.

A survey (Goldhill DR and Withington PS. 1993), presented to the Intensive Care Society in 1991, covering 64 ICUs in the United Kingdom found that only 35 of the ICUs had access to a microcomputer and only 32 of the units had a secretary or ward clerk (usually part time). Audit data was collected in 59 units, although this usually consisted of manually entered basic details placed into a register. Money for audit was available only in seven of the ICUs. The results of this survey suggested that intensive care audit was inadequately performed, and the resources and skills to improve this were unlikely to be forthcoming in individual units within the immediate future. Even where information was being collected, it was not identical in all units thus preventing meaningful comparison between the ICUs.

Collecting information on a form or register is only the first step in audit as the information has to be analysed to produce summaries of the process, and data on outcome for intensive care patients. Manual collation is time consuming and liable to inaccuracies in data organisation and manipulation, especially if large numbers of patients are to be considered. Computer hardware and software is readily available to process information once entered into a database, however nothing can be achieved without accurate data collection.

In theory much data can be accessed directly from other computer systems or patient monitoring equipment. Thus haemodynamic data, laboratory results and information

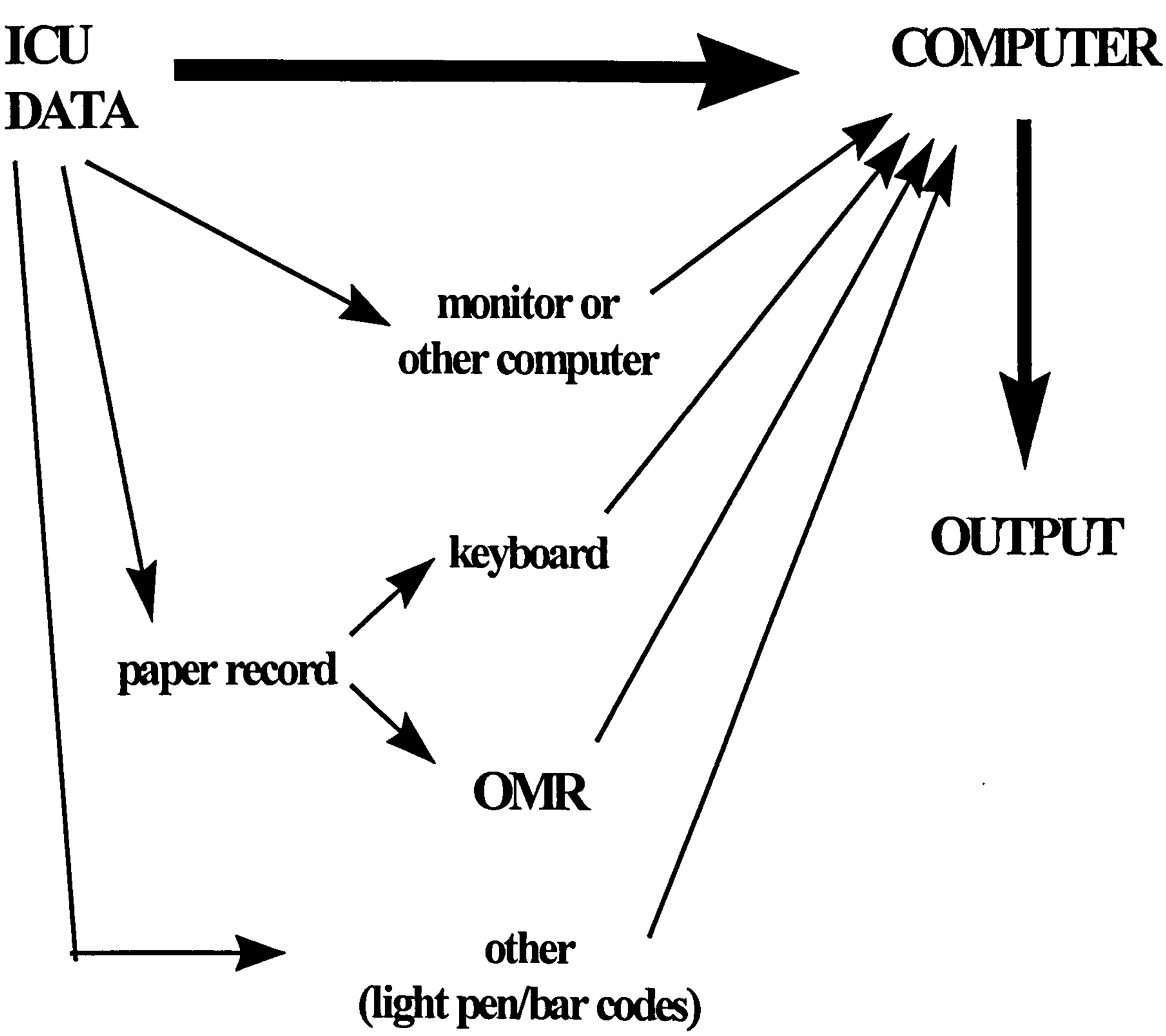
from the hospital's patient administration system (PAS) could contribute directly to an intensive care database. An information system such as this is expensive and requires a degree of integration of diverse sources of data that did not exist when our audit system was started and is still unlikely to be available for some time in most ICUs in the United Kingdom.

In addition there will always be important intensive care information that cannot be obtained directly from a computer or monitor. Such information includes elements of the APACHE II severity of illness score (Knaus WA et al. 1985) which encompasses the Glasgow Coma Score (GCS), selected physiological values and knowledge of chronic disease states. With suitable equipment, a keyboard, mouse or light pen can be used to enter such information directly into a computer. As an alternative hand held computers can be used at the bedside and data transferred at a later date to a central database. Unless all the data are available at one time these methods require multiple entries as well as a considerable investment in technology and training. The simplest and cheapest method is to manually complete a form for each patient and enter the data into the computer after the patient's death or discharge. Even with a small number of patients, entry of such data through a keyboard is time consuming and susceptible to transcription error. In addition each ICU needs access to its own computer and database.

The ICARUS system was one possible solution to the problem of intensive care data collection and analysis (figure 2.1).

Figure 2.1

Methods of data input into a computer database.



OMR = optical mark reader.

3. Background

Intensive care is a speciality with origins dating from at least 1923 with the opening of a postoperative neurosurgical unit at the Johns Hopkins Hospital in Baltimore. A premature baby care centre was opened in Chicago in 1927 and postoperative recovery rooms started to become common during the 1940's. The modern ICU developed from these recovery areas and from the experience of supportive ventilation gained during the poliomyelitis epidemics of the 1950s (Goldhill DR. 1997b, Reiser SJ. 1992). By 1958, in the United States, about 25% of the largest community hospitals had at least one ICU (Groeger JS et al. 1992, Groeger JS et al. 1993). Today all acute hospitals are expected to have at least one ICU and they have been accepted as necessary when treating severely ill patients

There is little doubt that admission to an intensive care unit is necessary for most critically ill patients. The staffing, organisation, equipment, experience and skills of the ICU team provide a level of support that is not available elsewhere in the hospital. However, little hard evidence has been published to prove the benefit of intensive care as it is very difficult to perform satisfactory scientific studies in this area (Luce JM. 1991). The wide range in the provision and quality of intensive care, the varied pathology and physiology of the ICU patients and the rapidly changing management of these patients make it extremely difficult to address this problem (Shortell SM et al. 1994, Goldhill DR. 1997b, Dragsted L and Qvist J. 1992). In addition, the use of many potentially life-saving interventions is limited to the ICU so that it is impossible to distinguish the intervention from the setting. Several studies have measured the cost of ICU in terms such as dollars per survivor (Dragsted L and Qvist J. 1992, Luce

JM. 1991, Jacobs P and Noseworthy TW. 1990, Rapoport J et al. 1994, Ridley S et al. 1993). These studies do not quantify the effect of ICU upon mortality.

The concept underlying intensive care is that patients who are critically ill, for whatever reason, are best treated by being grouped together. This allows for co-operative consultation, the concentration of suitably skilled staff and the rational and effective use of expensive and complex equipment. There is the assumption that where a high volume of patients are seen, for example with trauma, after cardiac surgery or aortic aneurysm surgery, complications are reduced and outcomes improved (Jones J and Rowan K. 1995). There is, however, little convincing evidence to support the hypothesis that regionalisation of ICU services significantly improves the outcome for critically ill adult patients (Purdie JA et al. 1990). There is some controversial evidence suggesting that regionalisation of paediatric intensive care may be beneficial (Ratcliffe J. 1998, Nicholl J. 1998, Nicholl J and Willats S. 1998, Pearson G et al. 1997). Not all ICUs are the same and it is probable that patients do better in specialised ICUs with appropriate leadership (Zimmerman JE et al. 1993b, Shortell SM et al. 1994). Individuals who become acutely ill or injured may therefore be subject to a macabre lottery in which access to appropriate care depends on where they live and on transportation and admission policies.

There is an increasing demand for intensive care (Jacobs P and Noseworthy TW. 1990). This is a result of an ageing population, better medical care so that more critically patients have a chance of benefiting from ICU admission, and a growing expectation among patients that they should have access to the "best" available treatment. Doctors contribute to the demand by their natural desire to provide

treatment to the limits of the available technology and knowledge. The difficulty in making decisions to limit or withdraw treatment, and the uncertainties of prognosis in ICU patients mean that emphasis is given to providing ICU treatment whenever benefit is possible. The supply of intensive care is limited by constraints on economic resources, by shortages of skilled staff and by perceived need.

In order to evaluate the effectiveness of intensive care and other models of looking after critically ill patients it is essential to gather information on the patients treated in the ICU. This information is also necessary to plan services and to allocate resources.

Minimum information includes details on the number of patients admitted to the ICU, their length of stay and whether they survived ICU and their stay in hospital. The patients admitted to the ICU are an extremely heterogeneous group. They have a wide range of pathologies, diagnoses and chronic health problems. The likelihood of a patient surviving an ICU admission is related to all these factors as well as their degree of physiological derangement and physiological reserve. In addition even the largest ICUs only admit a relatively small number of patients. For these reasons the average crude mortality of ICU patients varies widely between ICUs and may change over time within a unit because of unidentified factors such as changes in the local population, or in referral patterns for hospital treatment.

In order to compare the performance within and between intensive care units systems have been developed for predicting mortality of a group of ICU patients which take account of the varying diagnoses, physiological response and underlying health (Ridley SA. 1998, Rowan K. 1997, Wisner DH. 1992, Suter P et al. 1994, Seneff M

and Knaus WA. 1990). These systems are also essential when identifying patients for research as by stratifying subjects on the basis of predicted outcome smaller achievable studies can be carried out to assess the effect of treatment on outcome.

Systems have been described for assessing and comparing patients before anaesthesia or with organ dysfunction. These systems include the American Society of Anesthesiologists (ASA) scoring of preoperative patients (Cullen DJ et al. 1994) and the Glasgow Coma Scale (GCS) (Teasdale G and Jennett B. 1974, Jennett B. 1997) used for neurological assessment. Other scores include those predicting outcome in surgical cardiac patients (Parsonnet V et al. 1989), and describing the severity of pancreatic injury (Ranson JH et al. 1974) or respiratory failure (Murray JF et al. 1989).

The Acute Physiology and Chronic Health Evaluation (APACHE) score published in 1981 (Knaus WA et al. 1981) was the first general severity of illness "scoring" system designed to predict outcome in intensive care patients. Since then several other systems have been developed based either upon subjective methods, using a panel of experts to select variables and their weights, or with logistic regression techniques identifying variables associated with increased mortality. At present the most widely used systems for adult ICU patients are APACHE (II and III) (Knaus WA et al. 1985, Knaus WA et al. 1991), the simplified acute physiology score (SAPS I and II) (Le Gall J-R et al. 1984, Le Gall J-R et al. 1993) and the mortality probability models (MPM I and II) (Lemeshow S et al. 1988, Lemeshow S et al. 1994). Other systems such as the Pediatric Risk of Mortality (PRISM) (Pollack MM et al. 1996) and the Paediatric Index of Mortality (PIM) (Shann F et al. 1997) have

been developed for use in paediatric ICU patients. Other scoring systems such as the therapeutic intervention severity score (TISS) have been developed to quantify ICU workload and cost (Cullen DJ et al. 1974, Keene AR and Cullen DJ. 1983), or to assess the degree of organ failure (Marshall JC et al. 1995). The Revised Trauma Score (RTS) (Champion HR et al. 1983) and Injury Severity Score (ISS) (Baker SP et al. 1974) are combined to calculate a TRISS score (Boyd CR et al. 1987) used to predict outcome in trauma patients (Yates DW. 1990), many of whom will require intensive care.

In the United Kingdom the Intensive Care Society sponsored a large study using APACHE II (Rowan KM et al. 1993a, Rowan KM et al. 1993b). Although the system worked adequately to describe outcome in British ICUs there were differences between the two countries. The Intensive Care Society has since set up the Intensive Care National Audit and Research Centre (ICNARC), one of its aims being to introduce national intensive care audit. The ICNARC audit is presently based around the APACHE II severity scoring system.

Several large and growing databases now exist, particularly in the United States and Europe. There has been considerable discussion concerning data validity as well as publications comparing some of the techniques and their performance in different populations (Apolone G et al. 1996, Arregui LM et al. 1991, Barie PS et al. 1995, Bastos PG et al. 1996a, Beck DH et al. 1997, Burnette ES and Wunderink RG. 1995, Castella X et al. 1991, Castella X et al. 1995, Cho DY and Wang YC. 1997, Hersch M et al. 1994, Marks RJ et al. 1998, Meyer AA et al. 1992, Moreau R et al. 1989, Moreno R. 1997, Nouira S et al. 1998, Oh TE et al. 1993, Rocca B et al. 1989, Rowan

KM et al. 1994, Sirio CA et al. 1992, Wong DT et al. 1995, Wong DT et al. 1996, Zhu BP et al. 1996, Zimmerman JE et al. 1988). The information in the databases has been used to compare ICUs examining diverse factors such as the role of nutrition (Chang RW et al. 1986, Hopefl AW et al. 1989), a full time ICU director or the use of technology on outcome (Pollack MM et al. 1988, Manthous CA et al. 1997, Brown JJ and Sullivan G. 1989, Bastos PG et al. 1996b).

4. ICU data collection

In 1989 we considered several options for data collection and transfer into a computer database at the Royal London Hospital. These included:

A. A hand completed form entered into the computer through the keyboard.

B. Direct input into a computer at the bedside.

C. Input using bar coding.

D. Form completion by check boxes read into a computer with an optical mark reader (OMR).

E. Form completion by check boxes read into a computer with an OMR, with additional data entered manually through the keyboard.

Option A required a data entry clerk, was time consuming and incurred the additional risk of transcription error. There was no funding for the data collection and it was unrealistic to expect clinical personnel to be able or willing to enter data into a computer database.

The cost and limitations of computers were such that it was not feasible to place a computer by each bed or to use a portable computer for direct data entry [option B]. The potential exists to collect directly much of the necessary information by networking with the patient administration system (PAS), haemodynamic data, infusion pumps, laboratory data etc. Although considerable advances have been made in an attempt to achieve this, it is still not practical for most ICUs. Our survey of ICUs in 1991 (Goldhill DR and Withington PS. 1993) showed that only 35 out of 64

ICUs had access to a microcomputer and there was little in common in the operating systems and software of the computers. However, much progress has been made in computer technology since we devised our system.

Bar coding seemed to works well for individual items but was considered to be cumbersome for data such as dates and choices [option C].

There was some medical experience of OMR forms and our attention was drawn to this method by a feature in a medical newspaper. The OMR form was unsuitable for some essential information such as the patient's name. At the time our system was developed description of events leading to ICU admission or events occurring in the ICU could not be coded, although some progress towards this has been made since then. Option D was therefore rejected.

Form completion by check boxes read into a computer with an OMR, with additional data entered manually through the keyboard [option E] was selected as the method to be used. It has the following pros and cons:

Pro

Cheap (central processing, one computer for all patients, form inexpensive)

Professional-looking, colour coded form

Quick completion of form

Form backup in event of computer failure

Possibility of directly adding data from other sources in the future (e.g. PAS or laboratory analysers)

No transcription error from form to machine

Some data validation during computer entry

Con

Limited amount of data because of size of form

Unsuitability of some data for check boxes (e.g. physiological values, words)

Data not available for analysis until entered into computer

Omissions and errors on form not picked up until after patient discharge when notes may not be retrievable

Data analysed and kept remote from patients and from ICUs in the region

Limited manual data entry through keyboard still required

Errors (transcription, interpretation and incomplete data) when completing forms

Figure 4.1 shows the original OMR form used for intensive care audit at the Royal London Hospital.

Figure 4.1
Scan of the original Royal London Hospital intensive care audit form. **Page 1**

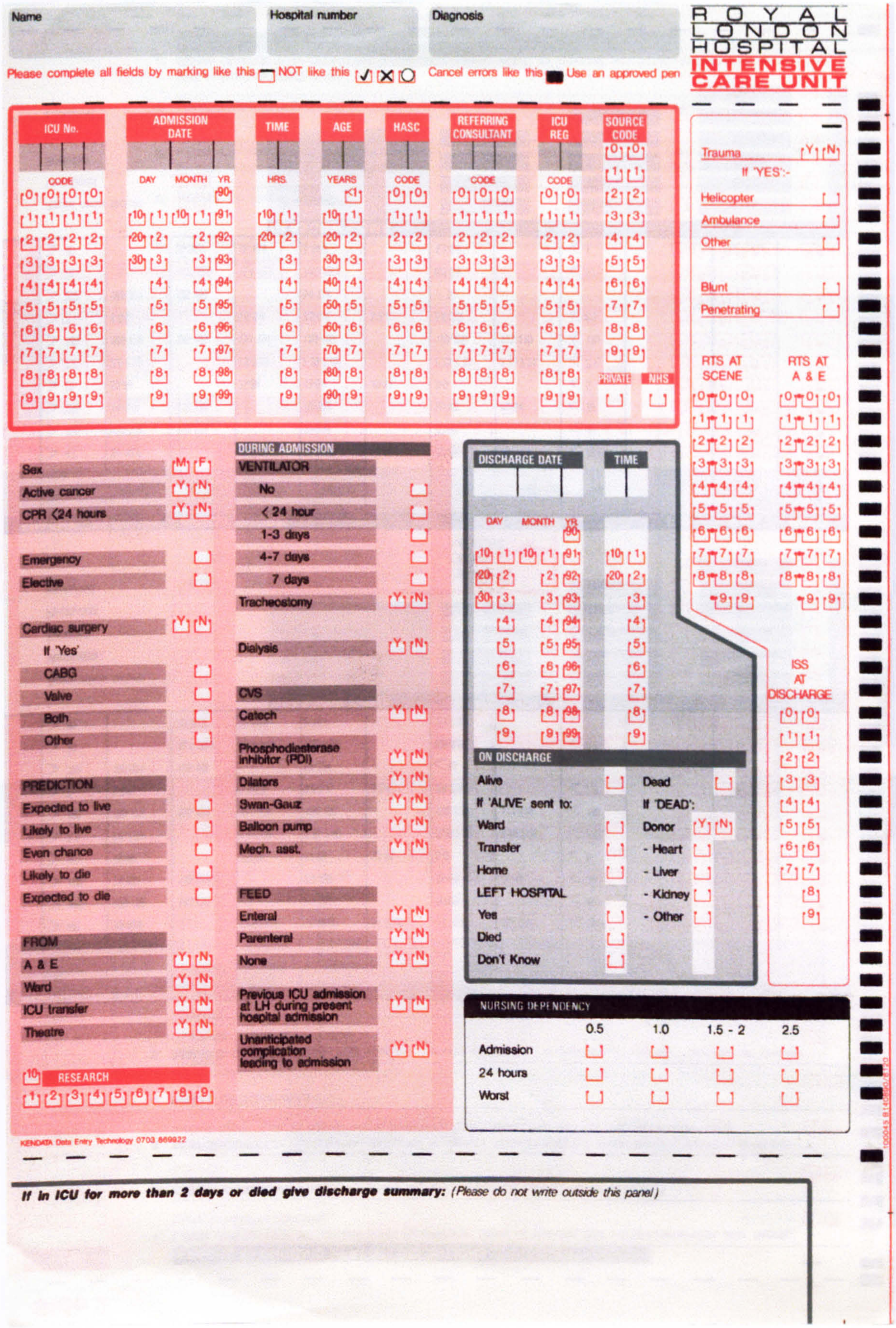
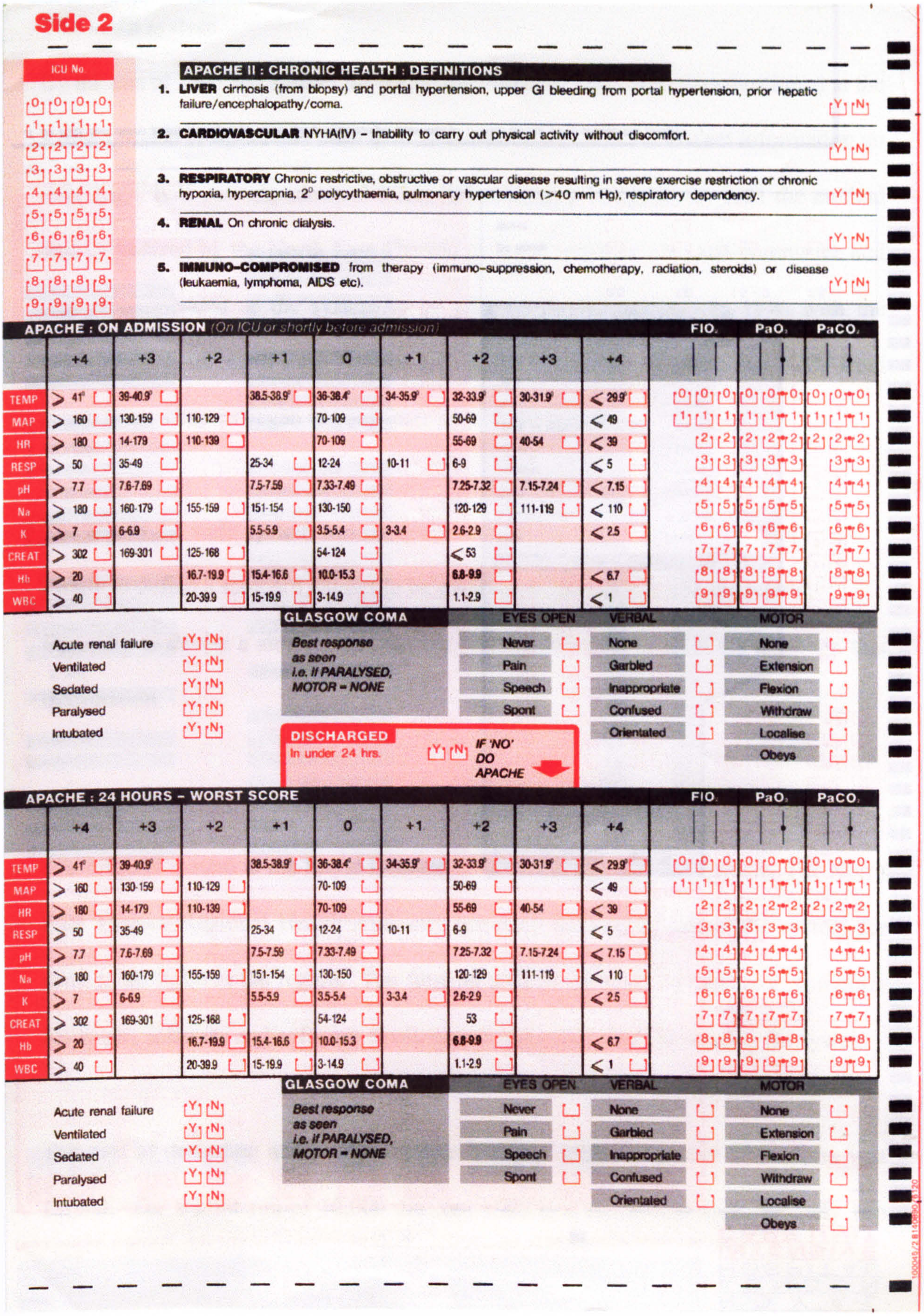


Figure 4.1
Scan of the original Royal London Hospital intensive care audit form. **Page 2**



Side 2

ICU No

APACHE II : CHRONIC HEALTH : DEFINITIONS

1. **LIVER** cirrhosis (from biopsy) and portal hypertension, upper GI bleeding from portal hypertension, prior hepatic failure/encephalopathy/coma. Y N
2. **CARDIOVASCULAR** NYHA(IV) – Inability to carry out physical activity without discomfort. Y N
3. **RESPIRATORY** Chronic restrictive, obstructive or vascular disease resulting in severe exercise restriction or chronic hypoxia, hypercapnia, 2° polycythaemia, pulmonary hypertension (>40 mm Hg), respiratory dependency. Y N
4. **RENAL** On chronic dialysis. Y N
5. **IMMUNO-COMPROMISED** from therapy (immuno-suppression, chemotherapy, radiation, steroids) or disease (leukaemia, lymphoma, AIDS etc). Y N

APACHE : ON ADMISSION *(On ICU or shortly before admission)*

	+4	+3	+2	+1	0	+1	+2	+3	+4	FIO₂	PaO₂	PaCO₂
TEMP	> 41°	39-40.9°		38.5-38.9°	36-38.4°	34-35.9°	32-33.9°	30-31.9°	< 29.9°	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9
MAP	> 160	130-159	110-129		70-109		50-69		< 49			
HR	> 180	14-179	110-139		70-109		55-69	40-54	< 39			
RESP	> 50	35-49		25-34	12-24	10-11	6-9		< 5			
pH	> 7.7	7.6-7.69		7.5-7.59	7.33-7.49		7.25-7.32	7.15-7.24	< 7.15			
Na	> 180	160-179	155-159	151-154	130-150		120-129	111-119	< 110			
K	> 7	6-6.9		5.5-5.9	3.5-5.4	3-3.4	2.6-2.9		< 2.5			
CREAT	> 302	169-301	125-168		54-124		< 53					
Hb	> 20		16.7-19.9	15.4-16.6	10.0-15.3		6.8-9.9		< 6.7			
WBC	> 40		20-39.9	15-19.9	3-14.9		1.1-2.9		< 1			

Acute renal failure Y N
Ventilated Y N
Sedated Y N
Paralysed Y N
Intubated Y N

GLASGOW COMA

Best response as seen i.e. if PARALYSED, MOTOR = NONE

EYES OPEN	VERBAL	MOTOR
Never	None	None
Pain	Garbled	Extension
Speech	Inappropriate	Flexion
Spont	Confused	Withdraw
	Orientated	Localise
		Obeys

DISCHARGED
In under 24 hrs. Y N *IF 'NO' DO APACHE*

APACHE : 24 HOURS – WORST SCORE

	+4	+3	+2	+1	0	+1	+2	+3	+4	FIO₂	PaO₂	PaCO₂
TEMP	> 41°	39-40.9°		38.5-38.9°	36-38.4°	34-35.9°	32-33.9°	30-31.9°	< 29.9°	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9	0 1 2 3 4 5 6 7 8 9
MAP	> 160	130-159	110-129		70-109		50-69		< 49			
HR	> 180	14-179	110-139		70-109		55-69	40-54	< 39			
RESP	> 50	35-49		25-34	12-24	10-11	6-9		< 5			
pH	> 7.7	7.6-7.69		7.5-7.59	7.33-7.49		7.25-7.32	7.15-7.24	< 7.15			
Na	> 180	160-179	155-159	151-154	130-150		120-129	111-119	< 110			
K	> 7	6-6.9		5.5-5.9	3.5-5.4	3-3.4	2.6-2.9		< 2.5			
CREAT	> 302	169-301	125-168		54-124		53					
Hb	> 20		16.7-19.9	15.4-16.6	10.0-15.3		6.8-9.9		< 6.7			
WBC	> 40		20-39.9	15-19.9	3-14.9		1.1-2.9		< 1			

Acute renal failure Y N
Ventilated Y N
Sedated Y N
Paralysed Y N
Intubated Y N

GLASGOW COMA

Best response as seen i.e. if PARALYSED, MOTOR = NONE

EYES OPEN	VERBAL	MOTOR
Never	None	None
Pain	Garbled	Extension
Speech	Inappropriate	Flexion
Spont	Confused	Withdraw
	Orientated	Localise
		Obeys

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History and description of ICARUS

The audit system

By the end of 1991 the system for collecting intensive care audit data developed at the Royal London Hospital had been used since January 1st 1990 to collect information on over 2,000 ICU patients admitted to the Royal London Hospital. In 1991 the method was considered by the North East Thames regional intensive care sub-committee and was recommended as the system to be adopted by the region. In 1996 with the amalgamation of North East Thames and North West Thames additional ICUs from North West Thames began to contribute data to the system.

The aim of the audit system was twofold:

Firstly to define a standard dataset to be gathered within all ICUs in the region.

Secondly to devise a simple, inexpensive method of enabling all ICUs to obtain this information.

Finance

The original system at the Royal London Hospital system was not funded. The North East Thames Regional Health Authority provided funding to extend the system for audit to all ICUs in the region. The funding paid for an audit co-ordinator, computer hardware, software and software development and office cost for running the system.

The cost of designing and producing proofs of the original regional OMR form was £1,200. For a print run of 10,000 the data collection forms cost approximately 15p

each (1992 costs). The double sided OMR reader with automatic paper stacking was £12,000 (1991 cost).

The regional grant covered hardware and software maintenance, the expenses of the audit co-ordinator and office expenses such as postage, stationary and telephone. Funding continued until April 1997 since when the audit co-ordinator has been supported partly by the Royal Hospitals Trust Directorate of Anaesthesia, Theatres and Intensive Care, and partly from subscriptions from participating ICUs. The software has been updated over the years and is now based upon Foxpro and is run on a computer with a Pentium processor.

Personnel

A regional audit co-ordinator was appointed in July 1992 to liase with individual ICUs to ensure that forms are completed correctly and accurately. The co-ordinator also checks forms for completeness before entry into the OMR, enters the limited number of free text fields and generates regular audit reports for individual ICUs and for the region.

Until 1993 the co-ordinator was Ms Judy Leach who was then replaced by Ms Annie Sumner. At the Royal London Hospital Mrs Ione Coleman assists the regional co-ordinator by helping with data entry and form checking. The database required considerable software development and this was carried out by Mr Nick Birch, a professional systems analyst. Dr Stuart Withington has been involved from the start sharing equally in the development and running of the system. In particular he was primarily instrumental in obtaining regional funding and in recruiting Mr Birch and

Ms Sumner. Considerable initial support and encouragement was given by Dr Peter Colvin and many other colleagues. The active participation of colleagues working in hospitals throughout the region has been essential for obtaining good quality data from so many hospitals over such a long time.

Organisation

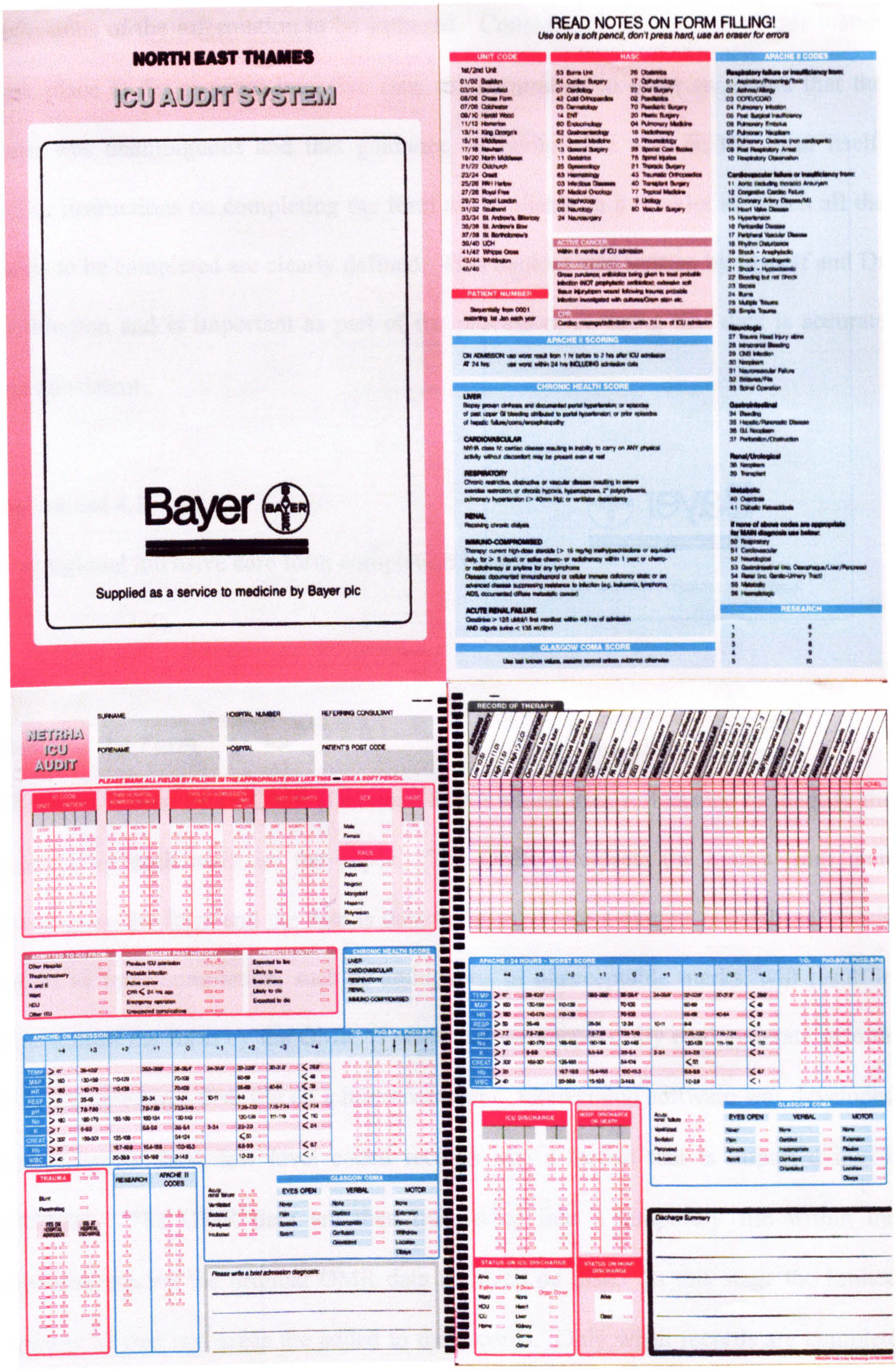
The regional ICU audit forms were initially offered to all ICUs within the North East Thames region. In 1992 these units admitted in total an estimated 8,000 patients per year and represent nearly 10% of all ICUs in the United Kingdom. Individual hospitals return the forms on a regular basis to a central data processing centre. The forms are entered through the OMR and data placed into a database. A few ICUs have chosen to participate in the regional database by contributing data collected onto their own database by other means. After analysis data is returned to the individual ICUs, as reports printed on paper, or on a disk to be read by a computer.

The regional audit form

The form used for regional audit is based on the original one previously used at the Royal London Hospital and incorporates the suggestions of the Intensive Care Society for the minimum data set required for intensive care audit (Intensive Care Society. 1990). The regional form is A3 size, double sided and perforated down the middle in order to be separated into two A4 size forms. One of the A4 forms contains instructions and codes to aid completion, and the other A4 form is for recording the information. One form is used per patient, data being collected on admission to the ICU, daily while on the ICU, and at discharge or death from ICU and hospital. These data include personal details of the patients, length of stay in the ICU, whether the

admission was unanticipated or associated with problems such as cancer, infection or a cardiac arrest, a measure of daily treatment and nursing dependency, and details on patient outcome after intensive care. A standard severity of illness score (APACHE II) (Knaus WA et al. 1985) is calculated from the data. In addition there are a limited number of free text fields entered through the computer keyboard. These include the patient's name, hospital number and brief summary of diagnosis and treatment. The various data areas are grouped together and colour shaded to identify the member of staff responsible for each area. The form allows a standard data set to be collected and information entered into a computer inexpensively and quickly. There are limitations, however, as once the form is typeset it is difficult and expensive to change the layout. The size of the form restricts the amount of data that can be gathered and the method is only practical for data that can be entered as a choice of a limited number of options or as a few simple numbers.

Figure 4.2
Scan of the regional intensive care audit form. (For original see document 4.1).



In order to have a meaningful database it is important that there is agreement on the definitions of the information to be gathered. Considerable discussion of this matter took place at the regional intensive care sub-committee in order to ensure that the form was unambiguous and that guidance on completion was on the form itself. Fuller instructions on completing the form are available in a booklet in which all the fields to be completed are clearly defined. This booklet was written by myself and Dr Withington and is important as part of the process of ensuring that data is accurate and consistent.

Document 4.2

The regional intensive care form completion booklet.

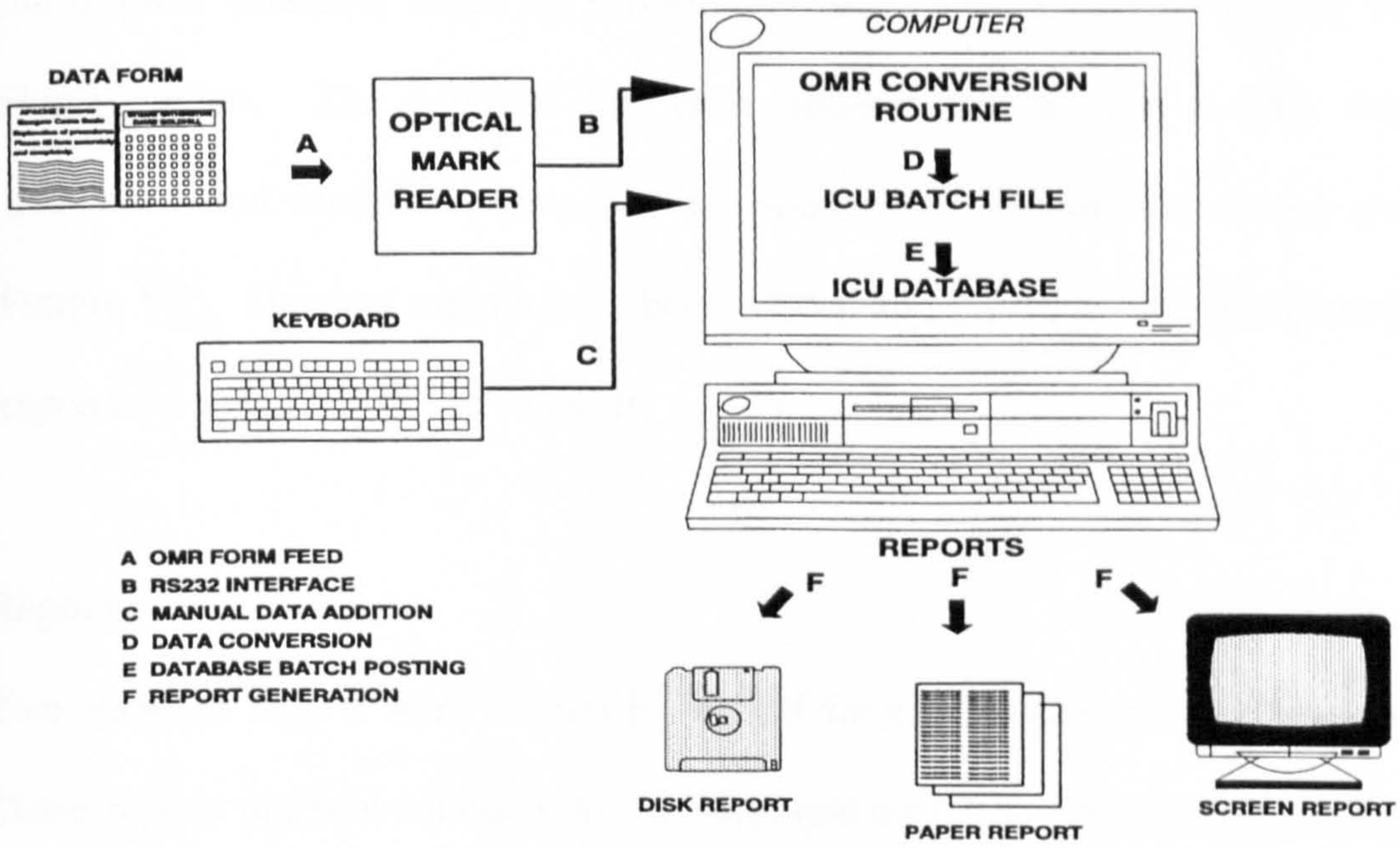
Reading the Form

The form is read by an OMR (Datascan 8400) which uses reflectance to identify the position of each mark on the paper. The OMR interprets the marks from their position on the form and the data is then transferred into a computer database. Basic errors of form completion, such as ambiguous or unacceptable marks, will result in rejection of the form by the OMR. Forms that are successfully read generate records that are saved in a disk file on a microcomputer. Conversion software was developed that converts these low level coded records into a format that is imported into a database. The OMR data are then transferred into a temporary file within the database leaving the original OMR data archived on disk. At this stage the limited number of free text areas are added to the records. Only when records are complete

can they be posted to the main database. Figure 4.3 shows the flow diagram of data acquisition and report generation.

Figure 4.3

Flow diagram of data acquisition and report generation.



Validation and security

Validation of the data begins with a visual check of the form. Simple error checking is incorporated into the OMR so that incomplete forms or those with mutually exclusive marks are rejected. Further error checking takes place within the database to reject obvious errors, such as patients discharged before admission, or duplication of records. Further checks are run within the database to identify anomalous data, and examples of this process include reviewing all records where a patient is 90 years or older, or where stay in ICU exceeds 30 days. To prevent unauthorised access the

computer room is locked and alarmed. The computer is also locked and access to the database requires a password. Copies of the data are regularly made onto floppy discs and the hard disc is backed up onto a tape streamer. The original data entry form is filed in a locked cabinet within the audit office and could be re-entered if necessary.

Output

The original database, based on Dataease software was run on a standard 486 PC microcomputer. The database has been updated and is now a fully featured, customised and modified version of a commercially available software package (Foxpro V2). Standard reports have been written and further reports are generated in response to specific needs or requests.

Reports

Two standard reports were written by myself for routine analysis of the audit data. These reports are sent routinely to the participating ICUs. When requested, further reports are generated by myself or, more usually, Ms Annie Sumner. Data is exported to other software such as Excel, Access or Powerpoint for further analysis and for presentation.

The standard reports contain the following data and layout.

1. Summary report

Figure 4.4 Summary report: **Page 1.**

SUMMARY REPORT ROYAL LONDON ICU — DATE OF REPORT 03/09/98

DATE OF ITU ADMISSION FOR FIRST PATIENT IN LIST 01/01/97
DATE OF ITU ADMISSION FOR LAST PATIENT IN LIST 31/12/97

NUMBER OF ADMISSIONS BY UNIT

UNIT	01	0	02	0	19	0	20	0	35	0	36	0
	03	0	04	0	21	0	22	0	37	0	38	0
	05	0	06	0	23	0	24	0	39	0	40	0
	07	0	08	0	25	0	26	0	41	0	42	0
	11	0	12	0	27	0	28	0	43	0	44	0
	13	0	14	0	29	837	30	0	45	0	46	0
	15	0	16	0	31	0	32	0	47	0	48	0
	17	0	18	0	33	0	34	0	49	0	50	0

TOTAL NUMBER OF ADMISSIONS IN THIS REPORT 837

Total admissions	837
planned surgery	114
emergency surgery	178
non-surgical	545

Total bed days	4402	Mean stay/admission	5.2
planned surgery	255	planned surgery	2.2
emergency surgery	1078	emergency surgery	6.0
non-surgical	3069	non-surgical	5.6

Number of admissions with previous ITU admission	113
Number of cardiac admissions with previous ITU admission	1
Number of trauma patients with previous ITU admission	12
Number of admissions with CPR <=24hrs before admission	118
Number of admissions with unexpected complications	130

NUMBER OF ADMISSIONS WITH ITU STAY		ICU MORTALITY PER STAY
Admission and Discharge same date	100	26
Duration of stay 1 day	244	52
Duration of stay 2 and 3 days	177	29
Duration of stay 4 and 5 days	93	23
Duration of stay 6 and 7 days	56	15
Duration of stay 8 - 14 days	96	26
Duration of stay 15 - 30 days	58	8
Duration of stay 31 - 90 days	12	1
Duration of stay >90 days	1	0

Number with NEGATIVE stay 0

	Number	Deaths in ITU	Deaths In hospital
Total number of cardiac admissions	1	0	1
vein grafts (code 60)	0	0	0
valve replacements (code 61)	0	0	0
vein grafts & valve replacements (code 62)	0	0	0
other cardiac operations (code 63)	0	0	0
Total number of trauma admissions	230	42	45

	All patients
No mortality data available in ITU	0
No mortality data available in hospital after ITU	7

	In ITU	In hospital
Total mortality	180	231

Figure 4.4 Summary report: **Page 2.**

SUMMARY REPORT ROYAL LONDON ICU DATE OF REPORT 03/09/98

NUMBER OF ADMISSIONS BY AGE

AGES	MALES	FEMALES	TOTAL	DEATHSBY AGE ITU	HOSPITAL
LESS THAN 1	2	1	3	0	0
1 - 4	4	3	7	0	0
5 - 9	9	7	16	0	0
10 - 19	30	20	50	8	8
20 - 29	65	41	106	23	25
30 - 39	53	33	86	13	13
40 - 49	70	33	103	19	24
50 - 59	85	44	129	34	42
60 - 69	103	59	162	38	54
70 - 79	82	55	137	33	45
80 - 89	19	19	38	12	19
90 +	0	0	0	0	0

AVERAGE AGE 50 AGE RANGE 0 - 89 YRS

HASCSPECIALITY	Number of admissions	Emergency surgery	Deaths ICU	Hosp	Total Bed Days
53 Burns	3	0	1	1	3
54 Cardiac Surgery	1	0	0	1	2
07 Cardiology	16	0	5	7	78
42 Cold Orthopaedics	3	0	0	0	4
05 Dermatology	1	0	0	1	1
14 ENT	1	0	0	0	1
60 Endocrinology	4	0	1	1	9
62 Gastroenterology	6	1	2	3	29
01 General Medicine	145	1	39	46	598
13 General Surgery	142	67	26	32	590
11 Geriatrics	2	1	2	2	2
25 Gynaecology	2	1	0	0	3
63 Haematology	16	1	10	12	204
03 Infectious Diseases	1	0	0	0	3
67 Medical Oncology	1	0	0	0	17
68 Nephrology	23	5	9	11	128
06 Neurology	20	1	3	4	163
24 Neurosurgery	243	94	58	76	1512
26 Obstetrics	9	9	0	0	12
17 Opthalmology	1	0	0	0	1
22 Oral Surgery	35	5	0	2	99
02 Paediatrics	9	0	0	0	20
70 Paediatric Surgery	2	0	0	0	3
20 Plastic Surgery	7	3	0	0	21
04 Pulmonary Medicine	32	1	7	10	187
18 Radiotherapy	0	0	0	0	0
10 Rheumatology	0	0	0	0	0
28 Special Care Babies	0	0	0	0	0
75 Spinal Injuries	8	3	1	1	57
21 Thoracic Surgery	5	3	0	0	59
43 Traumatic Orthopaedics	62	37	8	9	482
40 Transplant Surgery	4	2	1	1	17
77 Tropical Medicine	0	0	0	0	0
19 Urology	1	0	0	0	1
80 Vascular Surgery	32	10	7	10	96

The date the report was generated is shown in the upper right hand corner. The enclosed report is for 1997 and applies only to patients in unit 29 with a total of 837 admissions .

On the first page the total number of admissions is subdivided into planned surgical admissions, emergency surgical admissions and non-surgical admissions. Summary information of the total number and average number of bed days is given. Numbers of admissions with a previous ICU admission, who required cardiopulmonary resuscitation (CPR) or suffered unexpected complications are also given. A summary of the number of admissions by days spent in ICU is given along with the number of deaths. Details of cardiac and trauma admissions are also given and the number of those who died in ICU and hospital.

On the second page there are two tables. The first shows the number of admissions by age categories showing the number of males, number of females and deaths in ICU and hospital. In the second table the admissions are grouped by HASC (Hospital Activity Speciality Code) which is the speciality of the consultant under whom the patient was admitted to hospital. The reason for hospital admission may or may not be related to the reason for ICU admission.

A further report details admissions suitable for analysis with APACHE II (figure 4.5).

2. APACHE II report

Figure 4.5 APACHE II report: **Page 1.**

APACHE SUMMARY REPORT ROYAL LONDON ICU **DATE OF REPORT** 03/09/98

EXCLUDES
CARDIAC PATIENTS (HASC = 54)
BURNS PATIENTS (HASC = 53)
AGE < 16 YEARS
PREVIOUS ITU ADMISSION
PATIENTS WITH APACHE SCORES > = 55 AT ADMISSION OR 24 HOURS
PATIENTS WHERE HOSPITAL OUTCOME IS UNKNOWN

DATE OF ITU ADMISSION FOR FIRST PATIENT IN LIST 01/01/97
DATE OF ITU ADMISSION FOR LAST PATIENT IN LIST 31/12/97

NUMBER OF ADMISSIONS BY UNIT

UNIT	01	0	02	0	19	0	20	0	35	0	36	0
	03	0	04	0	21	0	22	0	37	0	38	0
	05	0	06	0	23	0	24	0	39	0	40	0
	07	0	08	0	25	0	26	0	41	0	42	0
	11	0	12	0	27	0	28	0	43	0	44	0
	13	0	14	0	29	666	30	0	45	0	46	0
	15	0	16	0	31	0	32	0	47	0	48	0
	17	0	18	0	33	0	34	0				

TOTAL NUMBER OF ADMISSIONS IN THIS REPORT 666

Total admissions	666		
planned surgery	103		
emergency surgery	152		
non-surgical	411		
Total bed days	3438	Mean stay/admission	5.1
planned surgery	227	planned surgery	2.2
emergency surgery	871	emergency surgery	5.7
non-surgical	2340	non-surgical	5.6

Number of admissions with CPR < =24hrs before admission 104
Number of admissions with unexpected complications 98

NUMBER OF ADMISSIONS WITH ITU STAY		**ICU MORTALITY PER STAY**
Admission and Discharge same date	82	23
Duration of stay 1 day	197	42
Duration of stay 2 and 3 days	142	26
Duration of stay 4 and 5 days	74	21
Duration of stay 6 and 7 days	38	9
Duration of stay 8 - 14 days	75	21
Duration of stay 15 - 30 days	48	7
Duration of stay 31 - 90 days	9	1
Duration of stay >90 days	1	0
Number with NEGATIVE stay	0	

	Number	Deaths In ITU	Deaths In hospital
Total number of trauma admissions	176	35	38

	In ITU	In hospital
Total mortality	150	191

No mortality data available in ITU 0
No mortality data available in hospital after ITU 0

Figure 4.5 APACHE II report: **Page 2.**

APACHE SUMMARY REPORT ROYAL LONDON ICU

DATE OF REPORT 03/09/98

NUMBER OF ADMISSIONS BY AGE

AGES	MALES	FEMALES	TOTAL
LESS THAN 1	0	0	0
1 - 4	0	0	0
5 - 9	0	0	0
10 - 19	13	6	19
20 - 29	53	35	88
30 - 39	47	32	79
40 - 49	61	25	86
50 - 59	72	37	109
60 - 69	89	51	140
70 - 79	64	45	109
80 - 89	19	17	36
90 +	0	0	0

MORTALITYBY AGE

ITU	HOSPITAL
0	0
0	0
0	0
3	3
17	19
13	13
16	19
29	36
34	48
26	35
12	17
0	0

HASC SPECIALITY	Number of admissions	Emergency surgery	Deaths ICU	Deaths Hosp	Total Bed Days
53 Burns	0	0	0	0	0
54 Cardiac Surgery	0	0	0	0	0
07 Cardiology	15	0	5	7	77
42 Cold Orthopaedics	3	0	0	0	4
05 Dermatology	1	0	0	1	1
14 ENT	1	0	0	0	1
60 Endocrinology	3	0	1	1	8
62 Gastroenterology	5	1	2	3	26
01 General Medicine	129	0	38	44	542
13 General Surgery	120	60	21	26	477
11 Geriatrics	2	1	2	2	2
25 Gynaecology	2	1	0	0	3
63 Haematology	15	1	10	12	128
03 Infectious Diseases	1	0	0	0	3
67 Medical Oncology	1	0	0	0	17
68 Nephrology	17	5	7	9	82
06 Neurology	10	1	1	2	113
24 Neurosurgery	173	62	44	57	1051
26 Obstetrics	9	9	0	0	12
17 Opthalmology	0	0	0	0	0
22 Oral Surgery	33	5	0	1	88
02 Paediatrics	1	0	0	0	3
70 Paediatric Surgery	1	0	0	0	2
20 Plastic Surgery	4	2	0	0	13
04 Pulmonary Medicine	26	1	7	9	151
18 Radiotherapy	0	0	0	0	0
10 Rheumatology	0	0	0	0	0
28 Special Care Babies	0	0	0	0	0
75 Spinal Injuries	4	2	0	0	40
21 Thoracic Surgery	4	3	0	0	42
43 Traumatic Orthopaedics	55	32	8	9	470
40 Transplant Surgery	3	2	0	0	6
77 Tropical Medicine	0	0	0	0	0
19 Urology	1	0	0	0	1
80 Vascular Surgery	27	8	4	7	75

Figure 4.5 APACHE II report: **Page 3.**

APACHE SUMMARY REPORT ROYAL LONDON ICU

DATE OF REPORT 03/09/98

APACHE II REPORT

TOTAL NUMBER OF ADMISSIONS IN THIS REPORT 666

NUMBER WITH ADMISSION APACHE SCORE GREATER THAN OR EQUAL TO 40 3
NUMBER WITH 24 HOUR APACHE SCORE GREATER THAN OR EQUAL TO 40 7

MAXIMUM SCORE AT ADMISSION 48
MAXIMUM SCORE 24 HOUR 46

AVERAGE OF HIGHEST APACHE SCORE FOR ALL ADMISSIONS 17

MIN APACHE SCORE 0
MAX APACHE SCORE 48

APACHE II SCORES

	ADMISSION APACHE SCORE			24 HOUR APACHE SCORE		
		DEATHS			DEATHS	
RANGE	NUMBER	IN ITU	IN HOSPITAL	NUMBER	IN ITU	IN HOSPITAL
0 - 4	67	1	2	179	29	37
5 - 9	152	8	14	173	29	35
10 - 14	158	26	33	89	12	21
15 - 19	129	42	53	80	18	24
20 - 24	83	29	39	68	17	25
25 - 29	48	22	27	40	18	21
30 - 34	15	9	9	24	15	16
35 - 39	11	10	11	6	6	6
40 - 44	2	2	2	5	4	4
45 +	1	1	1	2	2	2

HIGHEST SCORE WITHIN 24 HOURS

		DEATHS	DEATHS
RANGE	NUMBER	IN ITU	IN HOSP
0 - 4	51	1	2
5 - 9	125	6	10
10 - 14	135	15	21
15 - 19	122	29	41
20 - 24	99	29	37
25 - 29	61	20	26
30 - 34	38	22	25
35 - 39	23	17	18
40 - 44	6	5	5
45 +	6	6	6

RISK OF DEATH USING HIGHEST SCORE WITHIN 24 HOURS

		DEATHS	DEATHS
RISK OF DEATH	NO.	IN ITU	IN HOSP
0.00-0.1	242	13	21
0.11-0.2	126	20	30
0.21-0.3	65	11	15
0.31-0.4	42	14	14
0.41-0.5	58	20	28
0.51-0.6	26	7	8
0.61-0.7	27	11	16
0.71-0.8	23	12	14
0.81-0.9	34	25	27
0.91 +	23	17	18

Total No. Pts	Average WORST ROD	Actual deaths in Hospital	Expected Deaths	SMR
666	28.0%	191	186.90	1.02

The information at the top of the APACHE II report details the admissions that have been excluded to make the data suitable for APACHE II analysis. The date of the report, the period covered by the report and the number of admissions by ICU are shown. The example shown covers 1997 and applies to ICU number 29. The report shows that 666 out of the total of 837 admissions were suitable for APACHE II analysis.

The first two pages show similar data to that produced in the Summary report. Page three has three tables showing the number of admissions and deaths (ICU and hospital) by range of APACHE II score. One table refers to the admission score, the second to the 24 hour score and the third, which is based upon the highest values scored on either admission or 24 hours, to the highest score within 24 hours. The risk of death is calculated using the standard formula derived by Knaus et al (Knaus WA et al. 1985). The fourth table displays the number of admissions and the number of deaths, both ICU and hospital, by risk of death bands.

Finally details are given of the observed (actual) number of hospital deaths, the predicted (expected) number of hospital deaths calculated using APACHE II and the SMR (observed/predicted deaths).

Examples of other data analysis and presentations are in the studies described in this dissertation.

Discussion

The method outlined above has allowed a standard recommended data set to be collected for ICUs in the region. Participating hospitals have not needed an OMR, a computer, or specific audit personnel. The method is simple, does not require special expertise or training, takes little time for an individual ICU, and is relatively inexpensive. We feel we have demonstrated that it is achievable and sustainable. It has allowed us to accumulate a large and expanding ICU database.

5. Data accuracy and completeness

Introduction

ICARUS is a clinical audit system that was designed to collect useful ICU data from several units in a cost effective manner and without the need for expensive equipment or people. The method of data entry is designed to minimise the potential for errors. Data is gathered and entered onto the form at the patient's bedside. Most other systems also require much of the data to be gathered onto a paper form before entry into a computer database. The potential for data entry errors in these systems is probably higher than with our optical mark reader (OMR). The limited choice, and the definitions and explanations on the OMR form should help with consistency in data collection. Although the data collectors receive training and support from the regional co-ordinator, the potential for errors in data collection still exist. The data is collected in individual ICUs and processed centrally so that control over the data is inevitably not as close as one would ideally like it to be.

Definitions

There can be confusion over the definitions of certain items. Most of the confusion arises with aspects of the APACHE II data collection as the original paper by Knaus et al (Knaus WA et al. 1985) was not specific as to the definitions and timing of some of the data to be collected. This confusion still seems to exist. We obtained the answers to some of these uncertainties in personal correspondence with Dr Knaus. For example he wrote stating that data collection commenced up to one hour before the patient was admitted to the ICU. The data collection handbook (see Document 4.2) provides definitions for all the data collected on the audit form. In addition some

of the most important and confusing definitions are included on the audit form itself on the side opposite the data entry area. These items include the definitions for scoring chronic health abnormalities, and details of how to use the Glasgow Coma Score (GCS) in patients who are sedated or paralysed or otherwise unsuitable for assessment.

Missing data

Some data is almost certain to be missing, particularly from the APACHE II score. For example a patient without an arterial line is unlikely to have arterial blood gas results and therefore it will not be possible to score the pH or oxygenation variables. Not all patients will have routine blood analysis for haemoglobin, white cell count, creatinine, sodium or potassium. The GCS may be impossible to record because the patient is sedated by the time the patient reaches the ICU and it may not have been recorded beforehand.

Incorrect data

The APACHE II score requires that the most extreme values are recorded within the first 24 hours of ICU admission. Values for temperature, heart rate, blood pressure and respiratory rate are often measured continuously but only charted at intervals on a paper ICU record. Such chartings tend to miss out extreme values and this will be reflected in the APACHE II score. It should be noted that the values used to develop APACHE II were not obtained by automatic charting from monitors but were obtained in a similar manner to our data. Errors can also be made in charting the data from monitors, charts or laboratory results. The person filling in the form may fill in incorrect data through fatigue, incompetence or lack of concern. All missing data is

assumed to be within the 'normal' range and this introduces a consistent bias towards a lower score into the APACHE II scoring system.

Data entry into the computer

The system assumes that the OMR will correctly read the marked forms into the computer. Error is possible if the forms are misaligned in the reader, marked incorrectly (for example the boxes are filled in with too light a mark) or there is an error in the reader or translation software. Some of the data is entered through the keyboard and the potential for miskeying exists.

Data in the computer

Inaccuracies may exist because of programming errors. For example routines were written to calculate a patient's age from their date of birth and their date of admission to the ICU, and to calculate the APACHE II score and predicted risk of death. In addition routines were written to provide reports summarising the data.

There are thus several potential sources of error and the data in ICARUS was reviewed to identify and quantify the errors.

APACHE II, data accuracy and outcome prediction

Methods

Accuracy of data entered onto the audit form

Every 10th ICU chart of admissions to the Royal London Hospital ICU in 1995 and 1996 was examined. Patients after cardiac surgery, less than 17 years of age, who died or were discharged within eight hours of ICU admission or with a previous ICU admission were excluded to fulfil criteria allowing APACHE II scoring (Knaus WA et al. 1985). This left 122 charts for comparison.

The data on the charts was assumed to be completely accurate. Every charted value was reviewed and the highest and lowest values in the first 24 hours after ICU admission were recorded for the eight physiological variables listed in table 5.1. In our ICU the values of these variables are usually taken from the charts. APACHE II points were calculated and later compared to values in the ICU database. Core temperature and respiratory rate were charted hourly. Systolic (SBP) and diastolic (DBP) blood pressure were charted every hour and MAP was calculated as DBP + (SBP-DBP)/3. pH, sodium, potassium and haemoglobin values were measured in the ICU laboratory, typically every two to four hours. These were the values taken from the chart. The sodium, potassium and haemoglobin, along with white cell count and creatinine values, were also measured daily in the main hospital laboratory. These values were not checked.

The kappa statistic (Cohen J. 1960) and inter observer agreement were calculated as measures of inter observer reliability between the data in the ICU database and that found on chart review. A calculation was made of the total APACHE II score that would result if the values in the chart review were accurate. From this the predicted hospital mortality and the mortality ratio (MR, observed hospital deaths / predicted hospital deaths) were calculated. The calculation of the predicted hospital mortality was with original equation and coefficients published by Knaus et al (Knaus WA et al. 1985). The 95% confidence intervals of the MR were calculated using the method of Morris and Gardner (Morris JA and Gardner MJ. 1989). The observed mortality is regarded as a Poisson variable and its 95% confidence intervals are divided by the predicted mortality to derive the 95% confidence interval of the MR.

The accuracy of data entry from the audit form into the ICU database

Every 12th form (8.3% of admissions) was selected from 1706 patients admitted to the ICU at the Royal London Hospital in 1995 and 1996. The data in the ICU database was compared with that on the audit form. For data entered through "check boxes" the fields compared were the points for 10 physiological variables, patient date of birth and sex, hospital and ICU admission dates, ICU discharge date and ICU outcome. For each admission this comprises 33 "check boxes" on the audit form for a total of 4686 "check boxes". For the text data manually entered, the fields compared were the patient surname, the first two letters of the forename and hospital number.

A comparison of the ICU database and Patient Administration System (PAS) data

The PAS is the main hospital computer on which all patient details are entered. Information from 83 admissions, consisting of every 10th ICU admission between 1st January 1996 and 13th February 1997, was compared with PAS. The fields compared were hospital number, patient surname and forename, intensive care admission and discharge dates and ICU and hospital outcomes.

Results

Accuracy of data entered onto the audit form (table 5.1)

On chart review an average of 20.6% of the eight variables scored higher APACHE II points and 6.7% lower compared with the ICU database. The percentage inter observer agreement for APACHE II points ranged from a low of 61.5% for potassium to over 86% for sodium. If the values of the eight variables taken from the chart review are assumed to be accurate then the patients score an average of 1.73 APACHE II points more than actually recorded. This results in a predicted mortality of 27.8% compared with the 24.8% originally calculated.

Table 5.1

A comparison for 122 admissions of the APACHE II score and inter-observer agreement for 8 physiological values recorded in the ICU database and determined from ICU chart review.

	ICU database						charts					
	avg	% with points					avg	% with points				
variable	points	0	1	2	3	4	points	0	1	2	3	4
temperature	0.61	58	30	7	4	2	0.54	61	29	5	4	1
mean arterial BP	0.92	61	0	30	5	4	1.04	52	0	43	2	2
heart rate	1.19	48	0	40	7	4	1.70	23	0	64	11	2
respiratory rate	0.40	80	11	2	5	2	0.36	71	23	4	2	0
pH	0.92	61	8	14	10	7	1.19	42	22	18	11	7
sodium	0.34	80	5	15	0	0	0.57	70	4	26	0	0
potassium	0.39	71	20	7	2	0	0.69	46	40	13	1	0
haemoglobin	0.64	69	2	28	0	2	1.07	48	2	49	0	2
all 8 variables	**5.42**						**7.15**					

variable	% higher	% lower	kappa	% agreement
temperature	5.7	9.8	0.72	84.4
mean arterial BP	16.4	9.8	0.53	73.8
heart rate	28.7	5.7	0.45	65.6
respiratory rate	14.8	8.2	0.42	77.0
pH	27.9	5.7	0.51	66.4
sodium	13.1	0.8	0.65	86.1
potassium	32.0	6.6	0.34	61.5
haemoglobin	26.2	6.6	0.39	67.2
all 8 variables	**20.6**	**6.7**		

ICU database = data from ICU database; charts = data from chart review; avg points = average APACHE II points for each of the variables; % with points = the percentage scoring 0, 1, 2, 3 or 4 points for a given physiological variable; % higher = percentage with higher points on chart review; % lower = percentage with lower points on chart review; kappa = the kappa statistic describing the inter-observer difference between the ICU database and chart review for the APACHE II score. If X = the observed proportion of cases in which there is agreement between the ICU database and chart review and Y = the proportion of cases in which agreement would arise by chance then kappa = (X-Y)/(1-Y); % agreement = percentage of readings where the ICU database and chart review provided identical APACHE II points.

Of the 122 admissions, 22 (18.0%) died in the ICU and a further 24 after ICU discharge. The hospital mortality was thus 37.7% with 52.2% of the deaths occurring after ICU discharge. If the 46 observed hospital deaths are assumed to be a Poisson

variable, the 95% confidence limits of the observed deaths are 33.678 to 61.358. The change to the MR from the small change in APACHE II score is in table 5.2.

Table 5.2

Effect of chart review on number of deaths predicted and mortality ratio (95% confidence interval)

	predicted deaths	**MR (95% confidence interval)**
ICU database	30.25	1.52 (1.11-2.03)
chart review	33.96	1.35 (0.99-1.81)

predicted deaths = number of hospital deaths predicted using APACHE II. MR = mortality ratio (observed hospital deaths/predicted hospital deaths).

The accuracy of data entry into the ICU database. (table 5.3)

There were no errors in OMR data entry for the physiological variables, patient sex or ICU outcome. From the four dates per admission there was one error in reading from the OMR form. The date was marked as December (i.e. month 12). However, the mark on the 1 was faint and the OMR had read this entry as month 2, February. In addition to this ten dates marked on the audit form did not agree with the dates in the ICU database. Four were only one day different from PAS and four one month different from PAS. The ICU database agreed with PAS for all these dates indicating that errors in marking the OMR form had been detected and corrected with database maintenance.

For the data manually entered there were no errors in the surname or first two letters of the forename. Only one of the hospital numbers was incorrect where the figure "4" had been typed instead of "1".

Table 5.3

Errors with OMR data entry and keyboard entry. Results from 142 forms.

	variable	number of errors
entered through OMR	temperature	0
	mean arterial BP	0
	heart rate	0
	respiratory rate	0
	pH	0
	sodium	0
	potassium	0
	creatinine	0
	haemoglobin	0
	white cell count	0
	date of birth	0
	sex	0
	hospital admission date	1
	ICU admission date	0
	ICU discharge date	0
	ICU outcome	0
entered through keyboard	surname	0
	initials	0
	hospital number	1

A comparison of the data in the ICU database and in PAS (table 5.4)

There were five minor differences in hospital number. All the errors were because of illegible or incorrect writing of the number on the audit forms. There were three differences in the names. In two there was a difference of one letter in the surname. The other was a potentially serious problem as the OMR read details had been assigned to an incorrect patient name. This would have occurred as the data entered

through the keyboard was added to the OMR "check box" data. There were 11 disagreements in the dates for ICU admission and discharge. All the differences were of one day. It is likely that these differences were due to the way the PAS system is updated by ward clerks during normal working hours after a patient is transferred to and from the ICU. As the audit form is completed at the time of the transfer it is probable that the ICU data is more accurate than the PAS system. The ICU database and PAS entries for ICU outcome were in total agreement. There were two differences in hospital outcome. The PAS system recorded one patient as surviving hospital whom the ICU database had as dying. According to PAS the patient was briefly discharged from hospital, was readmitted shortly afterwards to hospital and then died. The other patient was recorded by the ICU database as surviving hospital and by PAS as dying in hospital.

Table 5.4

A comparison for 83 admissions of data in the ICU database and PAS.

variable	number of errors
hospital number	5
name	3
ICU admission date	5
ICU discharge date	6
ICU outcome	0
hospital outcome	2

Discussion

The marks made on our audit form were read accurately by the OMR into the computer. The method of manually adding a limited amount of text also proved to be satisfactory. The data in the ICU database showed good agreement with the PAS and is likely to be more accurate for some information. The largest potential error lies with the accuracy of the data taken from the ICU chart and entered onto the audit form.

The difference between the APACHE II points in the ICU database and those estimated from ICU chart review might arise for several reasons apart from errors in accurately recording the data. The charts review in this study was performed by one person. This ensured consistency in the method and interpretation but would not have prevented errors in data recording and comparison. Instructions for audit form completion allow values in the hour before ICU admission to be recorded. These values were not available on chart review but will explain only higher APACHE II points than those indicated by the ICU charts. In many cases there were transient highs or lows in temperature, heart rate and blood pressure. The doctor recording the physiological values may have ignored a transient, irrelevant abnormality. This may account for lower APACHE II points.

The chart review illustrates some of the problems associated with scoring APACHE II. Points are awarded for results within a certain range. The maximum score for each physiological variable is four, apart from creatinine where the points are doubled to a maximum of eight in acute renal failure, and the Glasgow Coma Score (GCS)

with a maximum of 12 points. A small difference in physiological value often results in a difference of two points in the score.

For example a heart rate of 105 scores no points and one of 110 scores two points. Heart rates less than 70 are common in healthy subjects but will score at least two points. A blood pressure of 175/85 is normal for many elderly patients. This gives a MAP of 115 which scores two points. A blood pressure of 100/50 will also score two points whereas a blood pressure of 100/55 scores no points. Very small differences in the actual blood pressure, or in the value charted, may make a substantial difference to the APACHE II score. Blood pressure and heart rate are usually continuously monitored in the ICU and it is likely that many patients will have at least one episode during their first 24 hours in ICU when their blood pressure or heart rate strays into the range of "abnormality" thus scoring APACHE II points. The ICU chart is unlikely to accurately reproduce all the highest and lowest monitored values. Even with charting every hour many patients scored APACHE II points for MAP or heart rate outside the "normal" range on one or two of the chartings in the 24 hours.

Similarly a respiratory rate between 12 and 24 scores no points whereas a rate of less than 12, which may be adequate for a ventilated patient with good respiratory function, will score at least one point. It was not uncommon for ventilator settings to be below 12.

The chart review also revealed that mild hyperventilation, causing respiratory alkalosis, is often associated with a pH of 7.5 or more thus scoring APACHE II points. With multiple blood testing it was common for at least one pH value to be

outside the "normal" range of 7.33 to 7.49. Similarly with multiple blood tests, the sodium, potassium or haemoglobin values were often outside the "normal" range on at least one sample. A patient on whom many blood tests is performed is therefore more likely to have a high APACHE II score than a patient with few blood results.

APACHE II scoring on patients dying in the ICU within 24 hours of admission may be inconsistent. For example should a patient be given points for physiological values as charted or should they be scored after death so that heart rate and blood pressure are taken as zero?

In addition to the eight variables studied, values for creatinine, white cell count, oxygenation and GCS are also scored in APACHE II. Errors with creatinine and white cell count may be less common as these are usually measured once a day in the laboratory and there is therefore less potential for errors. However, the creatinine points are doubled with acute renal failure. The definition of acute renal failure is not given in the original APACHE II paper and agreement on this is essential for consistent scoring. The oxygenation score may cause confusion, particularly with an FiO_2 greater than 0.5 where the alveolar arterial oxygen difference ($A\text{-}aDO_2$) must be calculated. Formulae for performing this calculation vary and the worst score may not be obvious from simple inspection of the blood gas results. It is with the GCS that the biggest potential for error arises. The maximum points that can be scored are 12 (15 minus the GCS). The GCS is difficult to assess in many ICU patients and it is essential that a consistent approach is taken to scoring the sedated or paralysed patient, or one in whom the GCS is unknown but suspected to be abnormal.

Outcome prediction also depends on the indication for ICU admission as well as the APACHE II score. These indications are imprecisely defined and only one can be selected to obtain the required coefficient. Different indications may markedly affect predicted mortality.

The number of deaths in our sample is small but demonstrates the effect on the MR of small changes in predicted outcome. With just 3.7 more predicted deaths the mortality ratio fell from 1.52 to 1.35. With over half of the deaths occurring after discharge from ICU the importance of post-ICU factors cannot be over-emphasised.

To determine the practice of other authors and provide an estimate of likely errors, other studies using APACHE II were reviewed. Index Medicus was searched under the combination of the textword APACHE II with the subject APACHE, restricted to focus, for the years 1995 to November 1997 in the journals Anaesthesia, Critical Care Medicine and Intensive Care Medicine. Eight articles were identified from authors other than ourselves.

Table 5. 5

A review of the use of APACHE II in intensive care publications.

Reference	Patients	Details of Scoring	Error checking
Knaus WA 1985	admissions to adult ICU in 13 USA hospitals, excludes coronary artery bypass surgery	most deranged value during initial 24hrs after ICU admission.	all 12 physiological values recorded for 87% of admissions, interobserver reliability reported to show 96% agreement for all physiological data
Beck DH 1997	excludes burn, ICU stay<4hrs, age<16yrs	"criteria and definitions described by developers", first 24hrs after ICU admission	none
Wong DT 1996	all trauma patients admitted to ICU	first 24hrs of ICU admission	none
Cho DY 1997	acute head injury	the 24hr period after entering hospital; includes the emergency room	none
Moreno R 1997	1st admission; excludes <18yrs, burn, acute coronary care, cardiac surgery, ICU stay<24hrs, patients still in hospital 2 months after end of data collection	most abnormal values during 24hrs after ICU admission	2nd set of forms completed for 5% intraclass agreement 0.88 or greater
Zauner CA 1996	chronic liver disease with cirrhosis, 1st admission, excludes ICU stay<24hrs, age<16yrs	at admission & after 48hrs	at admission 3% missing physiological data, assumed normal
Brown MC 1995	HIV positive who required ICU	from 2hrs before to 22hrs after ICU admission, or if died within 22hrs earliest recorded variables (not most abnormal)	missing data assumed normal
Ludwigs U 1995	acute myocardial infarction, 1st admission	"as described by Knaus et al"	77% of blood gas data, 7% haematology, 3% electrolytes and 3% vital signs missing
Wong DT 1995	adult, excludes neurosurgical, cardiac surgery, coronary care, burns.	reference, APACHE II, Knaus 1985	none

The literature review (Knaus WA et al. 1985, Beck DH et al. 1997, Wong DT et al. 1996, Cho DY and Wang YC. 1997, Moreno R. 1997, Zauner CA et al. 1996, Brown MC and Crede WB. 1995, Ludwigs U and Hulting J. 1995, Wong DT et al. 1995) (table 5.5) confirms that there are apparent inconsistencies in the application of APACHE II scoring and often insufficient information to determine the accuracy of data collection. If APACHE II scores are to be used for comparison between ICUs or within an ICU over a period of time the same rules for scoring must be applied. There

must be consistency in dealing with transient abnormalities, readings before ICU admission, values in patients dying in ICU and with anomalous or atypical abnormalities in one or two values from a series of results. The categorical nature of the scoring means that small differences in physiological values may cause large differences in the points scored. Clear rules for monitoring, charting and scoring are essential if outcome prediction is to be reproducible.

Our analysis is based upon an APACHE II database. Later developments of severity scoring systems generally provide greater guidance for data collection. It remains to be seen whether the newer scoring systems will provide more reproducible data over a period of time and between units.

In conclusion there were few errors using an OMR and keyboard to enter ICU audit data from an audit form into a database. The greatest potential for errors is with the definitions, chart recording and interpretation necessary for APACHE II scoring. The uncertainties and difficulties in scoring are likely to make it hard to maintain consistency in scoring between ICUs or even within the same unit over time. The potential differences in score identified by this study, although small, are sufficient to considerably alter the average predicted mortality and MR. MRs continue to be advocated as a valuable way to assess effectiveness of intensive care with differences in the MRs presumed to reflect differences in ICU performance (Seneff MG et al. 1997). Before these differences in MRs can be ascribed to true differences in intensive care practice we must be certain that they cannot be explained by the difficulties in data accuracy and consistency.

6. Uses and limitations of outcome prediction with APACHE II

The data in ICARUS has been used as a basis for critiques of the APACHE II method of comparing ICU performance. Although the analysis is confined to APACHE II the principles probably apply to the other commonly used methods of case mix adjustment for predicting outcome for ICU patients.

The following studies examine the effect of small changes in physiological values, post-ICU mortality and case mix on outcome predicted with APACHE II. The final part of this section discusses the reasons why intensive care prediction models may conceal preventable intensive care deaths, particularly in the United Kingdom.

Mortality predicted by APACHE II: The effect of changes in physiological values and post-ICU hospital mortality

Introduction

In his original paper on APACHE II (Knaus WA et al. 1985) Knaus stated that "This scoring system can be used to ... compare the efficacy of intensive care in different hospitals or over time". Analysis of a large ICU database suggests that there has been no noticeable improvement in the outcome of intensive care (ICU) patients when APACHE II is used to predict mortality (Rowan KM et al. 1993b). It may be that there has been little or no benefit from the many developments in the management of critically ill patients. An alternative explanation is the failure of physiologically

based intensive care scoring systems, such as APACHE II, to account for the effects of treatment outside of the ICU.

Patients admitted to the ICU have a wide range of underlying pathologies and physiological abnormalities. Scoring systems have been developed in order to allow comparisons in outcome between these patients (Suter P et al. 1994). Probably the most commonly used scoring system is APACHE II which assumes that there is a "strong and consistent underlying relationship between acute physiological derangement and the risk of death during acute illness" (Knaus WA et al. 1985). The APACHE II score is derived from 11 physiological variables (table 6.1), the Glasgow coma score (GCS), and the patient's age and chronic health status. The physiological variables score 0 if normal, and up to 4 points for abnormalities apart from the creatinine which scores double points (up to 8) in acute renal failure. Of the maximum 71 points, 6 depend on the patient's age, 5 on previous chronic health, 12 on the GCS and 48 on abnormalities in the physiological variables.

The age and chronic health components are fixed but most of the physiological variables are goals of treatment. The "worst" physiological values within 24 hours of ICU admission are scored and, with the possible exception of the white blood cell count and creatinine, it is often possible to improve values of the physiological variables with resuscitation. The patient's predicted mortality is calculated from their APACHE II score, a coefficient based on the reason for ICU admission (diagnostic category) and an additional weighting for emergency surgery.

Assuming the values of the physiological variables do not deteriorate after admission to the ICU, a patient resuscitated with improved physiological values before ICU admission will have a lower APACHE II score on admission, and therefore a lower predicted hospital mortality, than if the same patient is admitted to the ICU for resuscitation. If observed hospital mortality is unaffected by whether resuscitation takes place before or after ICU admission, the patient resuscitated before ICU will have a higher mortality ratio (observed hospital mortality/predicted hospital mortality) than the patient admitted to the ICU for resuscitation. In addition as APACHE II is based upon hospital, not ICU, mortality, differences in outcome after ICU discharge may also affect the mortality ratio. In this way alterations in ICU care may be masked by changes in pre-ICU resuscitation or post-ICU management.

We examined this hypothesis by analysing the data in ICARUS. The contribution of the physiological variables was identified to determine if pre-ICU treatment had the potential to alter APACHE II scores. We then calculated the effect on the predicted hospital outcome and mortality ratio of changes in the values of physiological variables. The effect of altered post-ICU mortality was also calculated by assuming a higher and a lower mortality after ICU discharge.

Methods

Data entered into the ICARUS database on all patients admitted to an ICU between the 1st January 1992 and July 31st 1995 was analysed. Data from four units that had entered fewer than 300 patients into the database were excluded. Patients admitted after cardiac surgery, with burns or less than 16 years of age were excluded, as was

data from patients with a previous ICU admission within six months or where ICU or hospital outcome was unknown. If physiological data was unobtainable (e.g. pH when blood gases were not available) values were assumed to be normal. The forms were only read into the computer and incorporated into the database when information on all physiological values was complete.

APACHE II scores were calculated from the worst values within 24 hours of ICU admission. The calculation of the predicted mortality was with original equation and coefficients published by Knaus et al (Knaus WA et al. 1985). We calculated the number of points contributed to the APACHE II score by each of the variables. We further divided the data into ten bands based on predicted mortality and measured the contribution made by the variables in each band. The mortality ratio (observed hospital mortality divided by predicted hospital mortality) was then plotted for each predicted risk of death band. The data was reanalysed assuming that the sum of the patient's 11 physiological scores (table 6.1) was increased by 2 or 4, or decreased by 2 or 4 to a minimum of 0. The data was then grouped by predicted mortality. The information was further analysed assuming that there were either 25% greater or 25% fewer hospital deaths for patients discharged alive from the ICU. The mean and ninety five percent confidence intervals for the mortality ratios were calculated as the observed hospital deaths divided by the mean and mean $\pm$ 95% confidence limits of the predicted hospital mortality. Differences between observed and predicted numbers of hospital deaths were tested with the Chi Square statistic.

Table 6.1

The 11 physiological variables contributing to the APACHE II score.

	maximum points
temperature	4
mean arterial blood pressure	4
heart rate	4
respiratory rate	4
oxygenation (either A-aDO_2 or PaO_2)	4
arterial pH	4
serum sodium	4
serum potassium	4
serum creatinine (with acute renal failure)	8
haematocrit or haemoglobin	4
white blood cell count	4

Results

Nineteen ICUs contributed a total of 21,152 complete ICU admission records. After excluding patients where hospital outcome was unknown (330), with previous ICU admission (2,013), less than 16 years of age (666), after cardiac surgery or with burns (6,311) and from four ICUs contributing less than 300 patients (484), data on 11,348 patients remained for analysis with a median of 623 (range 319 to 1921) admissions per ICU.

The percentage of patients with abnormalities (points >0) for the 11 physiological variables is shown in table 6.2. The average APACHE II scores contributed by the variables is also shown as are the average scores contributed by the 6 variables judged to be most easily influenced by treatment, (heart rate, mean arterial blood pressure, respiratory rate, pH, oxygenation, and haemoglobin). The 11 physiological variables contributed an average of 8.9 points to the APACHE II score, 54% of the total. The six selected variables contributed an average of 6.1 points, 37% of the total.

Table 6.2

Percentage of patients with abnormal physiological values.

	all patients	predicted mortality %									
		0-	10-	20-	30-	40-	50-	60-	70-	80-	90-
temperature	39.5	24.5	40.2	42.5	48.8	49.4	50.6	56.9	54.1	60.3	70.5
MAP	48.5	25.7	46.4	49.6	58.9	64.0	68.3	78.4	79.4	87.6	95.9
HR	54.4	35.4	53.8	58.9	66.3	66.4	69.5	73.0	79.6	84.1	89.5
resp rate	29.2	15.3	27.4	34.9	37.7	39.7	37.4	40.2	41.4	51.9	63.9
oxygenation	43.3	18.4	38.0	46.3	57.9	59.3	70.1	70.7	76.5	87.4	95.1
pH	10.6	3.2	8.3	12.9	13.9	16.0	19.8	18.6	20.2	20.9	28.6
sodium	25.1	11.4	22.7	28.0	34.9	33.5	37.2	40.2	45.7	44.6	53.4
potassium	29.3	9.5	24.6	31.9	36.0	41.8	48.6	49.0	55.7	63.5	85.9
creatinine	31.3	17.0	33.0	37.9	41.4	42.0	41.1	43.9	43.5	45.1	60.3
Hb	27.7	13.6	23.5	32.4	37.3	39.2	40.7	43.9	49.5	46.2	56.6
WBC	45.0	21.0	43.2	53.6	58.8	63.9	64.6	69.9	75.1	79.6	85.9
number of patients	**11348**	**4486**	**1710**	**1114**	**777**	**648**	**545**	**522**	**481**	**597**	**468**
average score	8.9	3.8	7.0	9.3	11.0	12.3	13.2	14.3	15.8	18.3	24.1
average score for 6 variables	6.1	2.8	4.9	6.4	7.6	8.3	8.9	9.6	10.6	12.4	15.4

The percentage of patients with abnormalities (≥ one point) in the physiological variables for all patients and also grouped by predicted mortality. Predicted mortality % 0- = 0 to <10% predicted mortality, 10- = 10 to <20% etc. The average APACHE II score contributed by the variables is shown and also that contributed by six variables judged to be most easily influenced by treatment (HR, MAP, resp rate, pH, oxygenation and Hb). MAP = mean arterial blood pressure; HR = heart rate; resp rate = respiratory rate; Hb = haemoglobin; WBC = white cell count.

Table 6.3 shows mortality ratio (95% confidence interval) for the normal data and for an increase in the physiological score of 2 or 4 points, or a decrease of 2 or 4 points to a minimum of 0. Of the total 3,692 deaths (32.5% of patients), 1,021 (27.7% of the deaths) occurred in hospital after discharge from the ICU. Table 6.3 shows the mortality ratio assuming 25% greater or 25% fewer deaths in hospital for patients discharged alive from the ICU. Figure 6.1 illustrates mortality ratios by predicted mortality.

Table 6.3

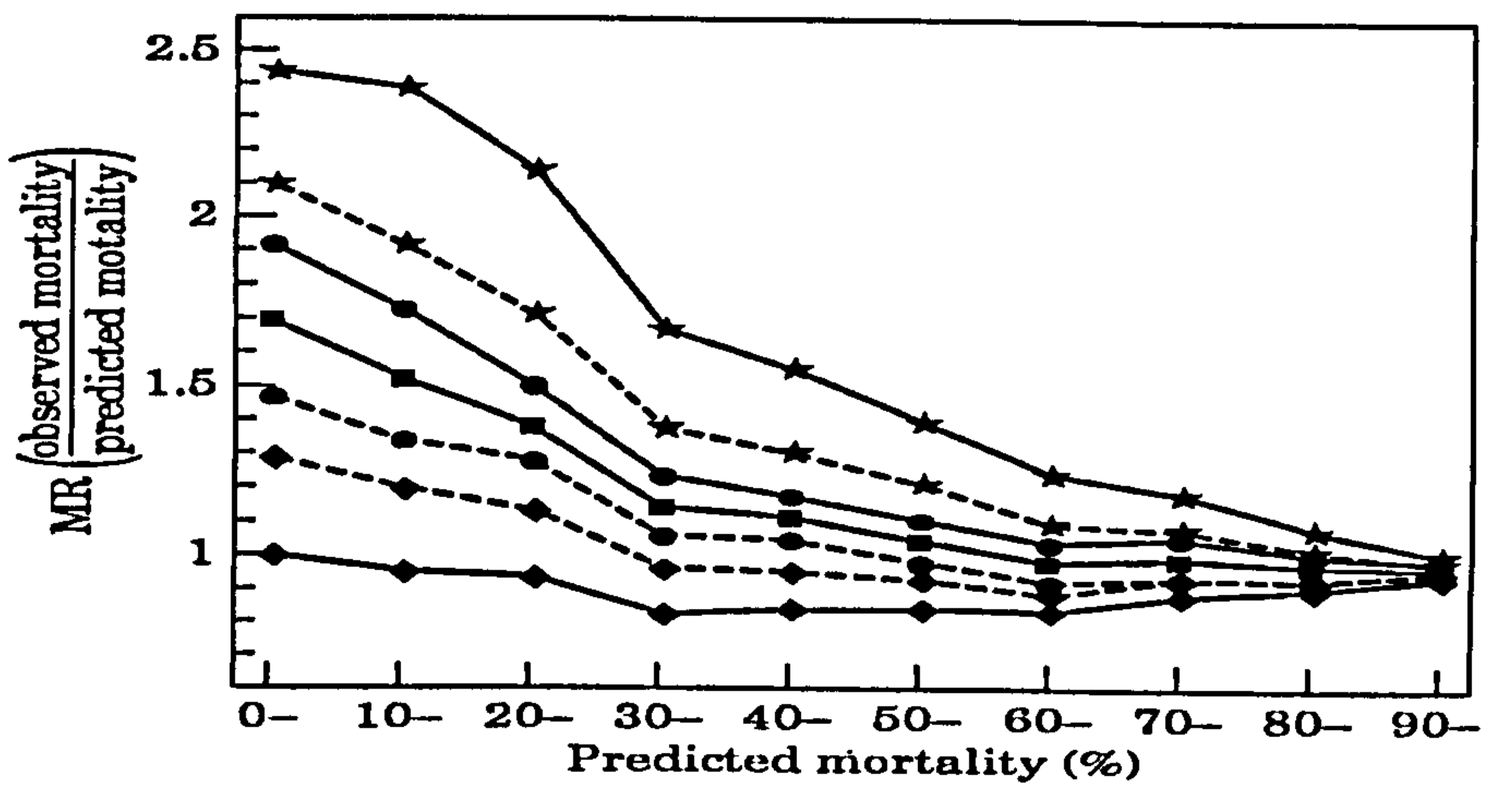
The effect on mortality ratios of an increase or decrease in physiological points scored or post-ICU mortality.

	MR	**(95% confidence interval)**
Physiological points minus 4 points	1.44	(1.41 to 1.47) **
Physiological points minus 2 points	1.27	(1.25 to 1.30) **
25% more deaths	1.21	(1.19 to 1.23) **
NORMAL data	1.13	(1.11 to 1.15) **
25% fewer deaths	1.05	(1.03 to 1.07) **
Physiological points plus 2 points	1.00	(0.98 to 1.02)
Physiological points plus 4 points	0.89	(0.88 to 0.91) **

Mortality ratios (MR) and 95% confidence limits for normal data and for an increase in physiological scores of 2 or 4 points, a decrease in physiological points of 2 or 4 to a minimum of 0, and an increase or decrease in post-ICU hospital mortality of 25%.
** significant at 1% level - observed compared to predicted
MR = observed number of deaths divided by predicted number
Physiological points = points contributed by physiological variables

Figure 6.1

Mortality ratios grouped by predicted mortality, for normal data and for the addition or subtraction of 2 or 4 points, and for 25% more or fewer deaths in hospital after ICU discharge.



Mortality ratios (MR) grouped by predicted mortality. This is shown for the actual data, for the addition of 2 or 4 points to the physiological scores, for the subtraction of 2 or 4 points from the physiological scores to a minimum of zero, and for an increase or decrease in post-ICU hospital mortality of 25%. minus 4, —✱—; minus 2, ---✱---; 25% more, —●—; actual, —■—; 25% fewer, ---●---; plus 2, ---◆---; plus 4, —◆—.

Discussion

Physiological-based scoring systems are widely used in intensive care to provide an objective prediction of outcome for a group of patients thus allowing description, stratification and comparison of the varied patients (Suter P et al. 1994). Data on APACHE II scoring applied to 8,796 patients in British and Irish ICU was published in 1993 (Rowan KM et al. 1993b). The overall mortality ratio of 1.02 (95% confidence interval of 0.98 to 1.06) suggests that there had been no significant improvement in patient outcome in the years since Knaus published his seminal paper (Knaus WA et al. 1985). However, there may be limitations in the APACHE II methodology so that improvements in care are not identified.

One limitation identified by Rowan et al (Rowan KM et al. 1993b) is the fact that case mix can significantly affect the mortality ratio (Goldhill DR and Withington PS. 1996a). Another limitation may be consistent differences in recording the data. In Knaus's original paper (Knaus WA et al. 1985) data was missing on 13% of admissions. Missing data is assumed to be within the 'normal' range thus scoring 0 points. In addition the most common scoring error is for the variable to be incorrectly scored as 'normal' (i.e. 0 points). If these are consistent errors then the APACHE II score and predicted mortality will be lowered resulting in a higher mortality ratio. A further limitation may be the effect of treatment before admission to the ICU or after discharge. In our analysis we have attempted to show the impact of such treatment.

Our analysis was performed on a large database consisting of real patient data. The importance of the analysis lies not in the accuracy, or otherwise, of our data but in the effect that small, clinically achievable changes to the APACHE II score have on

mortality predicted from this database. The database has also been used to illustrate the changes that would reflect alterations in post-ICU hospital mortality.

Relatively minor and frequent physiological abnormalities make a significant contribution to the APACHE II score. For example if the mean arterial blood pressure falls below 70 mmHg, the heart rate below 70 or the haemoglobin below 10 gm dl^{-1}, at least 2 points are scored for these variables. The average number of points contributed by physiological variables, and the high percentage of patients with abnormalities in these variables demonstrate that pre-ICU resuscitation could feasibly decrease the APACHE II score by 2 or more points.

The contribution of physiological abnormalities to the APACHE II score increases with predicted mortality. The potential of resuscitation to alter the APACHE II score is therefore increased with a higher predicted mortality. However even for patients with low predicted mortality (0-<10%), 35% scored points for heart rate, 25% for temperature and 26% for blood pressure (table 6.2). The average score for the physiological variables was 3.8 for this low risk group of patients. We chose to analyse the effect of altering the patients' APACHE II scores by 2 or 4 points with the proviso that the sum of the physiological variables could not be less than 0. This is a relatively large change in the APACHE II score for patients with a low predicted mortality and a small change for those with a high predicted mortality.

It is of interest that the mortality ratios from the normal data are high for low risk patients and as expected for the higher risk patients (figure 6.1). This may reflect the large effect that small differences between observed and predicted mortality have on

the mortality ratio in low risk patients. For example if observed mortality is 7.5% and APACHE II predicts a mortality of 5%, an inaccuracy of only 2.5%, the mortality ratio will be 1.5 (7.5/5). Thus even if APACHE II is fairly accurate in predicting outcome for relatively low risk patients the calculated mortality ratio may be misleading. This is important as the majority of ICU patients have a predicted mortality less than 20% (table 6.2).

The average mortality ratio for the patients in our units is 1.13 (table 6.3) indicating a higher observed mortality than predicted. Our analysis clearly demonstrates the dangers of using this figure to conclude that our units are performing badly. Pre-ICU resuscitation for emergency admissions may have improved physiological values resulting in APACHE II scores that are now lower on ICU admission than when Knaus wrote his original paper (Knaus WA et al. 1985). It is also possible that pre-ICU intraoperative management has altered so that physiological abnormalities are detected and corrected more aggressively. This would also result in lower predicted mortality. Although early resuscitation may also improve outcome our mortality ratio may reflect excellent pre-ICU resuscitation or intraoperative management. Such improvement need not be enormous as an average increase of only 2 points in the APACHE II score without a change in observed hospital mortality would return a calculated MR of 1.00 for our patients.

The Royal London Hospital contributed 16.9% of the patients in the study and we have some data on these patients to support the hypothesis. Patients with trauma comprised 13.9% of our hospital's non-cardiac surgery ICU admissions during this period. Many patients with trauma were brought to the hospital by helicopter after

initial resuscitation at the scene of the accident. From January 1991 to July 1992 there were 311 of these patients. Between the initial assessment at the scene and arrival in the emergency room there were improvements resulting in values within the 'normal' range in 73% of patients with a low blood pressure, 96% of patients with a low oxygen saturation, 80% of patients with an abnormally high or low heart rate, and 98% of patients with abnormal respiration. A similar improvement in physiological values before ICU admission is possible in other patients who arrive by ground transportation to our Accident and Emergency Department.

Admission after elective surgery contributed 31% of our non-cardiac surgery ICU admissions during the study period. In the first 6 months of 1993 51.2% of these patients scored APACHE II points for abnormal temperature for an average of 0.65 points. In the equivalent period of 1994, after introduction of warm air heating blankets into the operating theatres, the percentage of patients with temperature points fell to 31.7%, for an average of 0.34 points. For the same periods the average total points from the other 10 physiological parameters were 4.6 and 4.4 respectively. The percentage mortality was unchanged for these patients. This provides a degree of supporting evidence to suggest that changes in pre-ICU care may alter APACHE II scores without significantly altering outcome.

Much depends on the time at which the "worst" ICU results are recorded. Knaus et al refer to "the initial 24 h after ICU admission" (Knaus WA et al. 1985). In our group of ICUs we have agreed to include data from 1 hour before ICU admission, although in practice pre-ICU admission data is often not available or recorded. Even with this 1 hour inclusion many emergency admissions may arrive on the ICU several hours

after the initial resuscitation. In some hospitals patients may be admitted to the ICU for resuscitation. In other hospitals resuscitation will take place elsewhere. If the resuscitation is identical in efficacy and time of initiation and only differs in location, APACHE II scores for identical patients with identical outcomes will differ widely between the two hospitals.

Post-ICU care may also alter the mortality ratio by influencing the observed hospital mortality. In this way neglect after ICU increasing preventable deaths will increase the mortality ratio making the ICU look worse than it actually is. Alternatively, the percentage of hospital deaths after ICU may be related to the type of work undertaken by the hospital. For example, patients having major palliative cancer surgery, and those with haematological malignancies, AIDS or end stage chronic respiratory failure will have a high hospital mortality even if the acute ICU care is successful. With 27.7% of deaths occurring after discharge from the ICU these considerations may noticeably influence the mortality ratio. We used an increase or decrease of 25% in post-ICU deaths to illustrate this point.

If APACHE II, or another similar physiological scoring system, is used to predict outcome, interpretation of the results must take account of the time at which the values were recorded and the effect of pre and post-ICU care. The potential impact on predicted mortality of small changes in the APACHE II score is so large that great caution must be adopted in comparing results between different ICU or even within the same ICU over a period of time. Meticulous matched case control analysis may provide a method of confirming whether differences in the mortality ratio are a result of changes in practice outside or within the ICU. It is also essential to ensure that the

raw data on which the score is based is accurate and consistent. It is surprising for a system that has been so widely adopted that there is still confusion over basic definitions. For example there is no uniform definition of acute renal failure, policy for scoring the GCS in sedated or paralysed patients or even agreement as to when to start collecting the data. APACHE II was not designed to predict mortality for an individual patient and our analysis cautions against using it for this purpose.

The problem of treatment-influenced physiological variables was acknowledged by Knaus in his original paper (Knaus WA et al. 1985) when he stated that early recording of the values of physiological variables would make the score more independent of treatment. Other authors have commented on this shortcoming of the APACHE II system (Boyd O and Grounds RM. 1993, Dragsted L et al. 1989, Escarce JJ and Kelley MA. 1990). The APACHE III scoring system (Knaus WA et al. 1991) has examined the impact of gathering data before ICU admission although results suggest that this has little effect on the predicted outcome.

Despite all these potential inaccuracies the APACHE II system has been used and continues to be advocated as a system to rank ICU by patient outcome (Knaus WA et al. 1986, Knaus WA et al. 1993). It is possible that the inherent inaccuracies of a treatment-influenced physiologically based scoring system applied early during the ICU admission make meaningful comparisons impossible between ICUs or within an ICU over time. Modifications may be necessary to include measures of intervention or relevant physiological abnormalities which are not aims of treatment or easily altered by therapy. Changes in daily APACHE II scores may increase the model's predictive power but is only applicable to long stay patients (Chang RSW et al. 1988).

Our analysis clearly indicates that changes in management outside the control of the ICU, or inconsistencies in data collection or accuracy, may have an important effect on the mortality ratio. Improvements in ICU care may therefore not be detected by APACHE II. Unless account is taken of pre and post-ICU care the use of mortality ratios to rank ICU in "league tables" is likely to be inaccurate and misleading.

The effect of casemix adjustment on mortality predicted by APACHE II

Introduction

The APACHE II model was developed in order to predict mortality for groups of intensive care (ICU) patients (Knaus WA et al. 1985). An APACHE II score is determined from points based upon the patient's chronic health history, age, Glasgow coma score (GCS) and 11 physiological variables. The probability of hospital mortality for a single patient is estimated using the APACHE II score, a coefficient based on the reason for ICU admission (diagnostic category) and an additional weighting for post emergency surgery (Knaus WA et al. 1985). The probabilities of mortality for each patient are summed to provide an estimate of group hospital mortality.

If the 95% confidence intervals for the mortality ratio (observed hospital deaths divided by predicted hospital deaths) for a group of ICU patients incorporates 1.0 then

the model is accurate in predicting overall outcome. The APACHE II model was published in 1985 and is based upon a population of patients admitted to ICUs in the United States. The same model was applied by Rowan et al (Rowan KM et al. 1993b) to 8,796 patients in British and Irish intensive care units with an overall mortality ratio of 1.02 (95% confidence ratio 0.98 to 1.06). This suggests that the overall predictive power of APACHE II scoring has remained consistent over time and between countries. The paper by Rowan et al did show, however, that the mortality ratio varied considerably depending on the casemix of the population studied.

Patients admitted to the ICU present with a wide range of underlying pathologies and physiological abnormalities. It is unrealistic to expect the outcome of individual patients to be predicted accurately by APACHE II. However it is reasonable to assess the accuracy of the model by examining subgroups where those groups are based upon the factors that are part of the model. Using data from a group of British ICUs we examined the ability of APACHE II to adjust uniformly for casemix differences.

Methods

Data was analysed on all patients admitted to participating ICUs, and entered into the computer, between the 1st January 1992 and the 31st May 1994. Exclusions from the total number of ICU admissions were patients with admission to ICU within the previous 6 months, patients less than 16 years of age or who were admitted after cardiac surgery or with burns, and patients in whom ICU or hospital outcome was unknown. If physiological data was unobtainable (e.g. pH when blood gases were not available) values were assumed to be normal. The forms were only read into the

computer and incorporated into the database when information on all physiological values was complete.

APACHE II scores were calculated from the worst values within 24 hours of ICU admission. The calculation of the predicted mortality was with original equation and coefficients published by Knaus et al (Knaus WA et al. 1985). The mortality ratio (observed hospital deaths divided by predicted hospital deaths) was calculated for subgroups defined by predicted mortality, age, APACHE II score, diagnostic category, GCS, emergency surgery or other admission, and the chronic health points scored. For each subgroup the 95% confidence intervals for the predicted mortality were calculated as mean $\pm$ 1.96 (population standard deviation of predicted mortality/ square root of the number of patients in the population). The mean and ninety five percent confidence intervals for each mortality ratio were calculated as the observed hospital deaths divided by the mean and mean $\pm$ 95% confidence limits of the predicted mortality.

Results

Nineteen ICUs contributed a total of 11,757 complete ICU admission records. After excluding admissions after cardiac surgery (3,926), with burns (12), less than 16 years of age (423), with previous ICU admissions (1,072) and where hospital outcome was unknown (66), data on 6,258 patients remained for analysis. The number of patients contributed per ICU ranged from 23 to 798 with a median value of 321.

The mortality ratios (95% confidence intervals) for the subgroups are shown in table 6.4. Where possible the results published by Rowan et al (Rowan KM et al. 1993b)

are shown for comparison. There was a wide range in the value of the mortality ratio in the different casemix subgroups. For our patients predicted deaths were lower than observed for patients with a predicted mortality of less than 70%. The APACHE II equation provided a reasonable estimate of predicted outcome for patients up to age 55 but consistently under predicted mortality for patients who were older than this. Observed mortality was also underestimated for patients with APACHE II scores from 5 to 24. Mortality was underpredicted for non-operative patients with a primary reason for ICU admission in the respiratory and neurological systems and overpredicted for the cardiovascular system. There was accurate outcome prediction in patients with deep coma (GCS = 3) whereas in patients with a GCS of more than 8 observed deaths were higher than predicted. Mortality was also higher than predicted for patients without pre-admission chronic health indicators, for elective postoperative patients who scored chronic health points and for patients who were not admitted after emergency surgery.

Table 6.4

Mortality by casemix.

		Number of deaths in ICU and hospital							
		Observed		Predicted		Mortality			Rowan et al mortality ratio
	n	*n*	%	*n*	%	Ratio	95%	CI	
Predicted mortality (%)									
0–9	2483	161	6.5	107.7	4.3	1.50	1.46 to	1.53	0.97
10–19	910	203	22.3	132.4	14.6	1.53	1.51 to	1.55	1.20
20–29	610	207	33.9	148.1	24.3	1.40	1.38 to	1.41	1.09
30–39	394	161	40.9	137.0	34.8	1.18	1.17 to	1.18	1.13
40–49	359	177	49.3	161.8	45.1	1.09	1.09 to	1.10	0.99
50–59	282	162	57.4	156.3	55.4	1.04	1.03 to	1.04	1.02
60–69	304	200	65.8	198.0	65.1	1.01	1.01 to	1.02	1.00
70–79	274	194	70.8	205.2	74.9	0.95	0.94 to	0.95	0.92
80–89	362	295	81.5	307.1	84.8	0.96	0.96 to	0.96	0.93
90–100	280	252	90.0	263.8	94.2	0.96	0.95 to	0.96	0.89
Age group (years)									
16–25	522	78	14.9	76.63	14.7	1.02	0.91 to	1.16	0.88
26–35	631	115	18.2	124.70	19.8	0.92	0.84 to	1.03	0.85
36–45	597	127	21.3	124.73	20.9	1.02	0.93 to	1.13	1.05
46–55	767	216	28.2	197.35	25.7	1.09	1.02 to	1.19	0.98
56–65	1166	393	33.7	349.42	30.0	1.12	1.07 to	1.19	0.97
66–75	1571	606	38.6	548.86	34.9	1.10	1.06 to	1.15	1.02
76–85	880	413	46.9	346.71	39.4	1.19	1.13 to	1.26	1.15
≥ 86	124	64	51.6	48.92	39.5	1.31	1.15 to	1.52	1.43
APACHE II score									
0–4	738	18	2.4	18.55	2.5	0.97	0.92 to	1.02	0.14
5–9	1231	89	7.2	71.69	5.8	1.24	1.19 to	1.29	0.72
10–14	1100	211	19.2	134.05	12.2	1.57	1.52 to	1.63	0.97
15–19	931	298	32.0	219.89	23.6	1.36	1.31 to	1.40	1.00
20–24	780	337	43.2	303.90	39.0	1.11	1.08 to	1.14	1.11
25–29	607	357	58.8	351.25	57.9	1.02	0.99 to	1.04	1.09
30–34	436	325	74.5	328.64	75.4	0.99	0.97 to	1.01	1.01
35–39	250	208	83.2	215.64	86.3	0.96	0.95 to	0.98	
40–44	127	115	90.6	117.33	92.4	0.98	0.97 to	0.99	
Post-operative									
Respiratory	681	99	14.5	108.55	15.9	0.91	0.83 to	1.01	0.61
CVS	967	227	23.5	206.32	21.3	1.10	1.02 to	1.19	1.17
Neuro	192	47	24.5	37.03	19.3	1.27	1.12 to	1.46	1.57
GI	563	162	28.8	167.65	29.8	0.97	0.90 to	1.04	0.94
Renal	106	14	13.2	16.55	15.6	0.85	0.67 to	1.14	0.86
Metabolic	10	0	–	1.37	13.7	–	–		0.95
Haem	17	4	23.5	4.14	24.3	0.97	0.63 to	2.10	1.25
Non-operative									
Respiratory	1033	423	40.9	374.07	36.2	1.13	1.08 to	1.19	1.01
Cardiovascular	1658	517	31.2	569.99	34.4	0.91	0.87 to	0.95	0.96
Neuro	471	190	40.3	157.69	33.5	1.20	1.12 to	1.30	1.49
Gastrointestinal	222	112	50.5	101.98	45.9	1.10	1.02 to	1.20	1.02
Renal	88	31	35.2	27.65	31.4	1.12	0.94 to	1.39	1.10
Metabolic	183	35	19.1	30.16	16.5	1.16	0.93 to	1.54	0.53
Haem	38	16	42.1	12.34	32.5	1.30	1.00 to	1.84	1.59
GCS									
15	3452	651	18.9	485.9	14.08	1.34	1.29 to	1.39	–
9–14	818	269	32.9	230.8	28.21	1.17	1.10 to	1.24	–
4–8	616	244	39.6	265.4	43.09	0.92	0.87 to	0.97	–
3	1372	848	61.8	835.2	60.88	1.02	0.99 to	1.04	–
Emergency surgery									
Yes	1479	512	34.6	523.4	35.39	0.98	0.94 to	1.02	–
No	4778	1,500	31.4	1,292.0	27.04	1.16	1.13 to	1.20	–
Chronic health									
0 points	4620	1,237	26.8	1,124.0	24.33	1.10	1.07 to	1.14	–
2 points	1279	598	46.8	508.1	39.72	1.18	1.13 to	1.23	–
5 points	359	177	49.3	184.9	51.60	0.96	0.90 to	1.02	–

Discussion

Intensive care severity scoring systems are acknowledged as being of value for predicting outcome and comparing groups of ICU patient (Suter P et al. 1994). The original APACHE II equation was derived from data collected under study conditions by 13 hospitals in the United States. There are substantial differences in casemix between the original data and that from our group of ICUs. It is hardly surprising if the equation is imperfect when translated into routine clinical practice in a different country and a later time. The problems of relatively small numbers in some of the diagnostic categories and the dangers of relying on predicted outcome were recognised and highlighted by Knaus et al (Knaus WA et al. 1985). Nonetheless the APACHE II method has been widely adopted and accepted as a means of comparing outcome between ICUs and within ICUs over time (Knaus WA et al. 1986). In the United Kingdom the Intensive Care National Audit and Research Centre uses APACHE II as the basis for ICU audit. As the method is designed to adjust for casemix to allow for comparison of ICU outcome, it is important and pertinent to examine whether the casemix adjustment works for other sets of data.

Rowan et al highlight the effect of casemix on predicted outcome (Rowan KM et al. 1993b). In their database the original APACHE II method provided an accurate overall goodness of fit although it did not fit the data uniformly. There was a wide variation in the overall mortality ratio for individual hospitals and also for selected subgroups. The paper emphasised that if the equation does not fit then wrong conclusions may be drawn from the results. The findings of our analysis of casemix are similar in many respects to those of Rowan et al (Rowan KM et al. 1993b). There are, however, some striking differences. These are most marked in patients with a

low predicted risk of dying where the mortality ratio from our data is considerably higher than that they describe and this is also reflected in the excess mortality we observed in patients with a low acute physiology score and APACHE II scores of 5 to 24.

We have analysed the data by casemix factors that explicitly contribute to the APACHE II model. It should be realised that there is overlap between several of these categories. For example neurological patients may also have low GCS scores. In this way some of the groups examined may consist largely of the same patients. For surgical patients Rowan et al (Rowan KM et al. 1993b) found an excess mortality in cardiovascular and neurological patients, with a decreased mortality for respiratory admissions. This was not seen with our patients. It is particularly noteworthy that both ourselves and Rowan show a higher observed to predicted hospital mortality in patients in the non-operative neurological category. Compared to Knaus's data we appear to have a much higher proportion of admissions with a non-operative neurological diagnosis, and many of the patients will have presented with a head injury.

These differences in outcome by casemix may be genuine reflecting improved care for patients with a low mortality ratio and substandard treatment where there is a high mortality ratio. The differences may also be caused by variations in the timing and accuracy of data collection. Alternatively they may reflect the inability of the model to accurately adjust for the wide range of patients, pathology and physiological abnormality.

There are several reasons why APACHE II may not accurately predict outcome for our patients. We have shown that small consistent alterations in the APACHE II score will result in important changes in predicted mortality (Goldhill DR and Withington PS. 1996b). There are several ways that APACHE II data can be biased in a consistent manner. This may occur if a normal physiological score is recorded instead of an abnormal one. The effect of this is to decrease predicted mortality and increase the mortality ratio. Our method of data recording and entry largely avoids transcription and entry errors. Considerable effort is also made to ensure data accuracy and completeness. Nonetheless in a routine audit system and database of this size there will be errors. This is a problem with all such studies so that data was missing from 13% of admissions in Knaus's original paper (Knaus WA et al. 1985) and at least 20% of Rowan's (Rowan KM et al. 1993b).

There are other potential causes of a consistent bias in data. One ICU team may be involved in resuscitation and thus record physiological values from before the start of resuscitation in the emergency room. In another ICU physiological values may be recorded after resuscitation and on the patient's admission to the unit. For an identical patient the first ICU will record higher APACHE II scores, and thus predicted mortality, than the second unit. Similarly, because APACHE II predicts hospital, and not just ICU deaths, post-ICU care will affect the mortality ratio by influencing observed mortality. Thus good post-ICU care may consistently decrease the number of deaths and thus improve the mortality ratio. Changes in treatment may also influence the APACHE II score. For patients presenting in coma (GCS < 8) the model accurately predicts outcome from our data. However, with a GCS of >8 observed mortality is considerably higher than predicted. In our group of ICUs we

assume the GCS is normal unless we have evidence to the contrary. Many of our patients with head injury are resuscitated early and aggressively and this often involves elective sedation, paralysis, tracheal intubation and positive pressure ventilation. In these patients we record the last known GCS in the knowledge that the GCS may have deteriorated after the intervention but cannot be assessed. Thus the GCS may be artificially high resulting in a lower predicted hospital mortality.

An increase in the mortality ratio may therefore reflect biases in data collection such as a consistent decrease in APACHE II scores from physiological values wrongly scored as normal. Early, aggressive pre-ICU resuscitation and normalisation of physiological values in operative patients will also be reflected in decreased APACHE II scores and thus predicted hospital mortality on ICU admission. In addition it can be seen that small differences in predicted mortality will have a relatively big effect on the mortality ratio for groups with low predicted mortality. There are a large number of patients in the group with the lowest predicted mortality of 0 to 10% (table 6.4). Although the APACHE II equation predicted mortality to within 2.2% of observed, because the observed mortality is low this small difference between observed and predicted mortality results in a mortality ratio of 1.50.

The differences in predicted mortality by casemix suggest that great care must be used in interpreting outcome predicted using APACHE II. Rowan et al (Rowan KM et al. 1993b) stated that an 'APACHE II equation derived from British data might provide a better casemix adjustment than the existing American equation'. The differences in casemix specific outcome between our data and that of Rowan et al suggest that this is unlikely to be the case.

APACHE II has made an important contribution to our ability to describe the population and outcome of our ICU. While it provides a broad indicator of outcome our analysis suggests that local variations are such that careful interpretation is essential if it is to be used to provide accurate comparisons between ICU or even within ICU over time. Meticulous matched case control analysis may provide a method of confirming whether differences in the mortality ratio are a results of changes in casemix, in data collection or in practice outside or within the ICU. APACHE II was not designed to predict mortality for an individual patient and our analysis supports those who caution against using it for this purpose. Unless account in taken of casemix adjustment, using mortality ratios to rank ICUs is likely to be inaccurate and misleading.

Excess intensive care mortality in the United Kingdom may be concealed by ICU mortality prediction models

The comparative performance of intensive care units (ICUs) is measured with casemix adjustment systems such as APACHE, SAPS and MPM (Rowan K. 1997). These systems calculate predicted hospital mortality based upon reason for ICU admission, degree of physiological derangement, chronic health status, age and medical intervention. Predicted hospital mortality is calculated using data collected shortly before and after ICU admission (Rowan K. 1997).

There are considerable limitations to casemix adjustment systems (Goldhill DR and Withington PS. 1996a, Goldhill DR and Withington PS. 1996b). However, if the mortality ratio (MR; observed hospital mortality/predicted hospital mortality) is taken as an indicator of the effectiveness of ICU treatment, outcome is not clearly worse in the United Kingdom compared to elsewhere (Rowan KM et al. 1993b, Knaus WA et al. 1986, Wong DT et al. 1995, Bastos PG et al. 1996b, Knaus WA et al. 1993, Moreno R. 1997). If the average predicted hospital mortality of admissions, rather than the MR, is used to compare ICUs then large differences between countries emerge.

From the ICARUS data the average predicted hospital mortality by APACHE II (Knaus WA et al. 1985) for 12,762 patients from 15 ICUs in this database is 28.6%. Another British ICU database reports a predicted hospital mortality of 27.2% (Rowan KM et al. 1993b). In other countries average predicted mortality is generally lower, for example 19.8% (Knaus WA et al. 1986), 18.8% and 15.1% in the United States (Zimmerman JE et al. 1993b). Out of 37 ICUs in the United States four reported an average predicted hospital mortality of more than 25% (Zimmerman JE et al. 1993b) whereas only two of 15 ICUs in North Thames had a predicted mortality less than 25%. Data from over 13,000 ICU admissions in the United Kingdom, eight other European countries and North America showed that the British hospital mortality for these patients was highest at 32.4% compared with a median of 21% for the other European countries and 19.7% for North America (Le Gall J-R et al. 1993). Preliminary data from the European Consortium for Intensive Care Data (ECICD) using SAPS II to assess severity of illness show that intensive care patients in the United Kingdom are sicker that any of the eight other participating countries (ECICD

abstract, not published). A Canadian study reported a predicted hospital mortality of 24.7% (Wong DT et al. 1995) and one of 20% was calculated for a group of Brazilian ICUs (Bastos PG et al. 1996b).

Patients already in hospital account for a high proportion of high-risk ICU admissions. In our data, ICU admissions from the ward are 21.7% of total admissions. These have a 52.9% hospital mortality (1466 deaths), compared with 22.3% (1156 deaths) of those admitted from the operating room/recovery and 30.2% (1081 deaths) from the accident and emergency department. Of patients admitted to ICUs following external cardiac massage or defibrillation 42.9% (677 patients) came from the ward. These patients had a 79.5% mortality. In our own hospital 34.8% of ICU admissions of patients who had been in hospital at least 24 hours were following a respiratory or cardiac arrest on the ward (Goldhill DR et al. 1999). In 1996 there were 142 cardiac arrest calls to the wards following which 33 patients (23%) were admitted to the ICU.

Our research (Goldhill DR et al. 1999) and that of others (Franklin C and Mathew J. 1994) suggests that it is possible to identify early those ward patients likely to require ICU admission or suffer a cardiac arrest. Early recognition of these patients may allow management to prevent deterioration in physiological values or to prevent arrest. Such intervention is likely to improve outcome. The incidence of cardiac arrest on the ward may therefore be a useful indicator of the quality of care. Compared to the United Kingdom, in some other countries a higher percentage of resources is given to caring for critically ill patients (Bion J. 1995b) and ICU admissions have a lower average predicted mortality suggesting that patients are

likely to have access to appropriate care earlier. If patients are identified early and admitted to the ICU, in particular before a respiratory or cardiac arrest, their predicted mortality will be less but, given appropriate ICU treatment, so will the observed mortality. There will be no difference in the MRs and no indication of the improved ICU outcome.

The relative lack of critical care resources and the high predicted mortality of patients admitted to British ICUs point to the possibility of an excess mortality compared to better resourced medical systems. Early identification of critically ill patients may help improve care for these patients on the ward or facilitate early admission to an appropriate high dependency area or ICU. This is likely to decrease the number of deaths without altering the MR. The use of casemix adjustment systems to compare ICU performance will conceal rather than reveal this excess mortality.

7. An analysis of information in the database

This includes an investigation of the patient groups most likely to benefit from intensive care and strategies to improve outcome in patients admitted to the intensive care unit.

Outcome of intensive care patients in a group of British intensive care units

Introduction

Intensive care is expensive and scarce (Ryan DW. 1996). One measure of the usefulness of intensive care is the cost per life saved. Ways of reducing the cost per life saved include increasing the percentage survival following intensive care and lowering the cost of caring for non-survivors. Admission to the ICU should be restricted, therefore, to those patients with a reasonable expectation of benefiting (Jennett B. 1984). This excludes patients whose death is inevitable as well as those patients who should survive and do well without the need for intensive care. Intensive care is only one episode in the continuum of care for the patient who passes through the ICU. Events affecting outcome for the ICU patient may occur even before the patient arrives in hospital. Thus the responses of the primary care doctor, the emergency services and even bystanders performing resuscitation may be essential in determining the patient's survival (Nichol G et al. 1996a, Nichol G et al. 1996b, Gallagher EJ et al. 1995). Once in hospital the

treatment and decision making in the emergency room, in the operating room or on the ward may all be important.

Although there are difficulties in drawing firm conclusions from risk adjustment methods used to compare outcome for ICU patients within and between ICUs (Goldhill DR and Withington PS. 1996a, Goldhill DR and Withington PS. 1996b), there is little evidence from standardised mortality ratios (Knaus WA et al. 1986, Rowan KM et al. 1993b, Knaus WA et al. 1993, Wong DT et al. 1995, Bastos PG et al. 1996b, Moreno R. 1997) or outcome of patients with organ failure (Zimmerman JE et al. 1996) that mortality for ICU patients is decreasing despite advances in therapy, technology, training and resources. This may be because intensive care management can only have a small impact on mortality of patients admitted to the ICU. With some patients there may be little that can be done in the ICU to alter outcome because by the time of ICU admission the underlying pathology is so severe and irreversible. Other patients die after discharge from the ICU. In some of these patients death is inevitable but in others the care received after the ICU may affect what will be recorded as an ICU death. Patients who stay in ICU more than a few days consume a disproportionate amount of resources. Early identification of the long stay patients who will not survive and from whom treatment could be withheld or withdrawn would also be useful.

If outcome is to be improved for ICU patients it is important to identify the groups of patients at risk of dying. Resources and initiatives can then be targeted to those groups of patients most likely to benefit. An analysis of the ICARUS data was undertaken looking, in particular, at those patients who died in ICU or after discharge from ICU to see whether pre or post-ICU events were likely to contribute to their deaths. As a

secondary aim I looked to see whether it was possible to identify early those longer stay patients who eventually died and thus consumed ICU resources with little or no benefit.

Method

I analysed data entered into the database on all patients admitted to an ICU participating in ICARUS between the 1st January 1992 and April 31st 1996. In accordance with the criteria for analysis with APACHE II (Knaus WA et al. 1985), patients admitted after cardiac surgery, with burns or less than 16 years of age were excluded, as was data from patients with a previous ICU admission within six months or where ICU or hospital outcome was unknown. Data was excluded from units that had entered fewer than 300 patients into the database. It was felt their patients may be unrepresentative and data less accurate due to unfamiliarity with the data collection method. If physiological data was unobtainable (e.g. pH when blood gases were not available) values were assumed to be normal.

CPR (cardiopulmonary resuscitation) was defined as cardiac massage or defibrillation within 24 hours of ICU admission. Reasons for ICU admission were divided into 41 specific categories and a further seven broad categories (respiratory, cardiovascular, neurological, gastrointestinal, renal, metabolic, haematological) for patients who did not fit one of the specific categories. These admission categories were all mapped to those described for APACHE II scoring (Knaus WA et al. 1985) in order to predict outcome based on APACHE II. APACHE II scores were calculated from the worst values within 24 hours of ICU admission. The calculation of the predicted risk of hospital death (ROD) was with original equation and coefficients published by Knaus et al (Knaus WA et al. 1985).

Information was extracted on patients who were admitted to ICU and died, either in ICU or after an ICU admission but during the same hospital admission. Analysis included the number of patients admitted after CPR, patient location before ICU admission, duration of ICU stay, the number of patients by admission diagnosis and categorization by APACHE II score and risk of death predicted by APACHE II. The 95% confidence intervals were calculated for the mortality ratio (observed hospital mortality / predicted mortality) using the method of Morris and Gardner (Morris JA and Gardner MJ. 1989). The observed mortality is regarded as a Poisson variable and its 95% confidence intervals are divided by the predicted mortality to derive the 95% confidence interval of the mortality ratio. The goodness of fit of the mortality distribution was assessed with the χ^2 test of Lemeshow and Hosmer (Lemeshow S and Hosmer DW. 1982). Duration of stay in ICU was defined as the number of days between the ICU admission and discharge dates with a minimum stay of one day. Because of the typically skewed pattern of ICU stay the mean value is not appropriate (Weissman C. 1997). I have given the harmonic mean, which is the reciprocal of the arithmetic mean of the reciprocals of the data, as well as the value of the 75^{th} centile as a measure of the tail in the longer stay range. Student's t-test and chi-squared test were used where appropriate.

Results

A total of 23,331 admissions with complete records were available from 24 ICUs. After excluding 6,710 patients admitted for cardiac surgery or after burns, 862 patients less than 16 years of age, 1,859 second or subsequent ICU admissions, 268 admissions where outcome was unknown and 870 admissions from units contributing fewer than 300

datasets, a total of 12,762 admissions from 15 ICUs were selected for analysis. Details of the units are in table 7.1. A consultant session approximates to one half day per week of qualified medical input into the ICU. The consultants supervise doctors training in intensive care who provide much of the routine medical management on the ICU.

Table 7.1

Details of individual ICUs.

unit	type	ICU beds	hospital beds	consultant sessions
A	non-university	5	437	7
B	university	18	420	18
C	non-university	6	444	10
D	non-university	4	427	7
E	non-university	4	546	9
F	non-university	6	530	7
G	non-university	4	197	7
H	non-university	5	363	5
I	university	12	618	15
J	non-university	6	780	10
K	university	4	398	4
L	university	14	950	15
M	non-university	5	400	7
N	non-university	4	259	3.5
O	university	10	678	10

type = type of hospital, university = teaching/university, non-university = district general hospital/non-university; ICU beds are an estimate of average beds available; each consultant session approximates to one half day of consultant time per week dedicated to the ICU.

Overall mortality

Hospital mortality was 32.5% (4151 patients). For individual ICUs the mortality range was 23.5% to 41.3% with a median of 34.7% (table 7.2).

Table 7.2

Demographic and clinical characteristics of ICU admissions.

unit	number of patients	stay harm	stay 75th	age	ROD	% deaths	% deaths after ICU	MR
A	652	1.6	4	62.5	0.382	34.7	30.5	0.91
B	796	1.4	3	51.7	0.270	25.4	36.6	0.94
C	525	1.9	6	51.4	0.351	33.1	17.8	0.94
D	319	1.9	5	61.5	0.351	37.3	25.2	1.06
E	874	1.4	3	61.4	0.340	37.4	24.2	1.10
F	774	1.7	5	59.2	0.339	37.9	18.1	1.12
G	472	1.6	4	65.1	0.334	37.7	27.0	1.13
H	1247	1.4	3	61.6	0.306	35.2	31.0	1.15
I	536	2.1	8	54.4	0.292	34.0	18.7	1.16
J	722	1.5	3	60.5	0.315	36.7	25.3	1.16
K	319	1.3	2	49.1	0.277	32.9	45.7	1.19
L	2355	1.6	5	50.6	0.239	29.0	29.6	1.21
M	1658	1.4	2	60.0	0.193	23.5	28.5	1.22
N	697	1.6	3	62.7	0.262	33.1	23.8	1.26
O	816	1.7	5	51.4	0.309	41.3	25.5	1.34
Total	**12762**	**1.6**	**4**	**57.1**	**0.286**	**32.5**	**27.1**	**1.14**

stay = stay in days as harmonic mean (harm) and 75th centile (i.e. for unit O the stay of 1.7 and 5 indicates a harmonic mean stay of 1.7 days and a 75th centile stay of 5 days. The harmonic mean is the reciprocal of the arithmetic mean of the reciprocals of the data); age = average age (years); ROD = risk of death predicted with APACHE II; % deaths = % of patients who died in hospital; % deaths after ICU = % of hospital deaths that took place after ICU discharge; MR = mortality ratio (observed hospital deaths/predicted deaths).

Crude mortality and ICU stay varied widely by admission category (table 7.3).

Table 7.3

Hospital mortality and ICU stay by ICU admission category.

admission category	No.	% deaths	died stay harm	died stay 75th	lived stay harm	lived stay 75th
cardiogenic shock	284	77.5	1.3	2	2.0	5
post respiratory arrest	309	64.7	1.9	6	2.0	8
sepsis	472	58.9	1.7	6	2.5	8
pulmonary infection	575	57.4	2.5	10	2.6	10
intracranial hemorrhage	409	55.3	1.7	3	1.9	6
congestive cardiac failure	232	47.4	1.7	4	1.6	4
GI perforation/obstruction	535	43.9	1.8	5	1.7	4
hypovolaemic shock	204	43.1	1.5	2	1.6	4
GI hemorrhage	304	43.1	1.9	7	1.4	2
rhythm disturbance	495	40.8	1.4	2	1.3	2
hepatic/pancreatic disease	308	40.6	2.0	9	1.5	3
COPD	277	36.5	2.1	9	2.0	8
hematologic	107	35.5	1.8	5	1.5	3
neurologic	148	33.1	2.0	5	1.9	4
cardiovascular	328	32.6	1.4	3	1.3	2
ischaemic heart disease/MI	1104	32.2	1.3	2	1.3	2
aspiration	154	31.2	1.9	7	1.5	4
renal	227	29.5	2.0	7	1.3	2
gastrointestinal	242	26.4	1.7	6	1.5	3
postoperative insufficiency	542	24.2	1.9	8	1.5	3
multiple trauma	585	22.7	1.7	7	2.4	10
aortic aneurysm	902	22.7	1.9	9	1.5	3
head injury alone	353	22.1	2.0	4	1.8	5
GI neoplasm	370	21.6	1.9	8	1.5	3
respiratory	280	20.4	2.0	7	1.5	3
peripheral vascular disease	165	19.4	1.5	2	1.2	2
renal neoplasm	130	13.8	1.5	3	1.2	1
hemorrhage - not shocked	156	12.8	2.0	8	1.3	2
asthma	214	12.6	2.0	9	1.5	3
seizures	167	12.6	2.0	10	1.4	3
respiratory observation	780	11.8	1.6	5	1.2	2
overdose	324	11.1	1.7	5	1.2	2
simple trauma	258	3.5	1.4	2	1.3	2
total	**11940**	**32.8**	**1.7**	**5**	**1.5**	**3**

ICU admissions for all admission categories with more than 100 patients. No. = number of patients; % deaths = % of patients who died in hospital, stay = stay in days for those that lived and those that died given as harmonic mean (harm) and 75th centile (75th) (i.e. for simple trauma the stay for those that died of 1.4 and 2 indicates a harmonic mean stay of 1.4 days and a 75th centile stay at 2 days. The harmonic mean is the reciprocal of the arithmetic mean of the reciprocals of the data); GI = gastrointestinal, COPD = chronic obstructive pulmonary disease, MI = myocardial infarction. When the reason for admission did not fit within a more specific category the primary system involved (e.g. respiratory, cardiovascular etc.) was selected.

Stay in ICU

There was a highly significant difference ($p<0.01$) in the distribution of ICU stay between survivors and non-survivors. Of non-survivors, 45% were in ICU for 1 day or less, 66% of deaths were within 3 days and 75% within 5 days. Only 12% of non-survivors were in ICU for more than 10 days. Stay varied by intensive care unit and by admission category (table 7.2 and 7.3) and in some admission categories there is a difference in stay between survivors and non-survivors.

Age

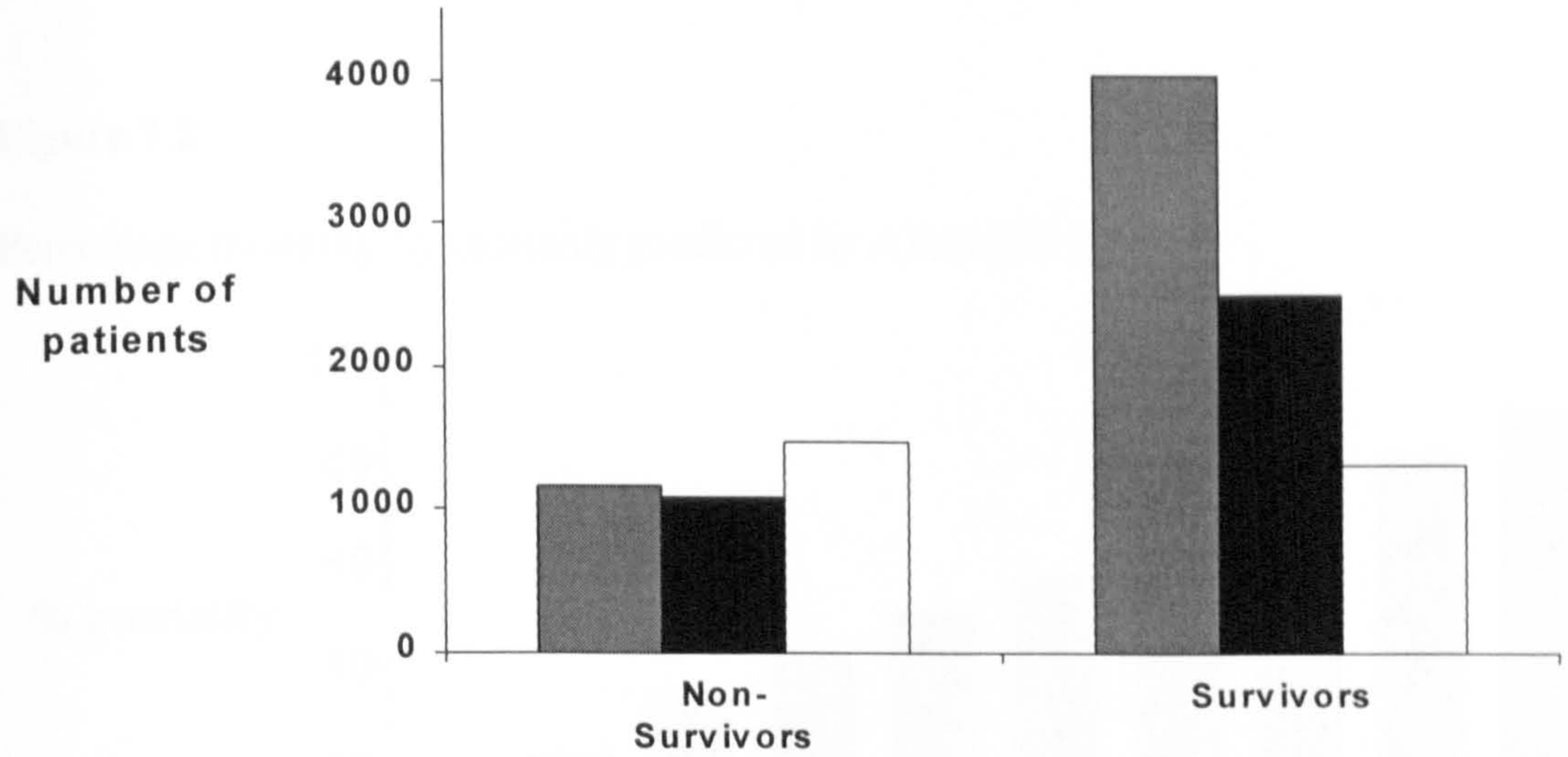
There was a highly significant difference ($p<0.01$) between the average age of survivors, 54 years (SD 19), and non-survivors, 63 years (SD 17). Percentage mortality increased with increasing age as did the percentage dying in hospital after surviving a first ICU admission.

Location before ICU admission

The ***number*** of non-survivors was similar between patients admitted from operating room/recovery and the emergency department, with the highest number admitted from the ward. Ward admissions had a much higher percentage mortality (52.9%) than patients admitted from either operating room/recovery (22.3%) or the accident and emergency room (30.2%) (fig 7.1). There was a highly significant difference ($p<0.01$) in pre-ICU location between survivors and non-survivors.

Figure 7.1

Pre-ICU location and outcome.



Operating room/recovery, grey filled bars; emergency room, black filled bars; ward, open bars.

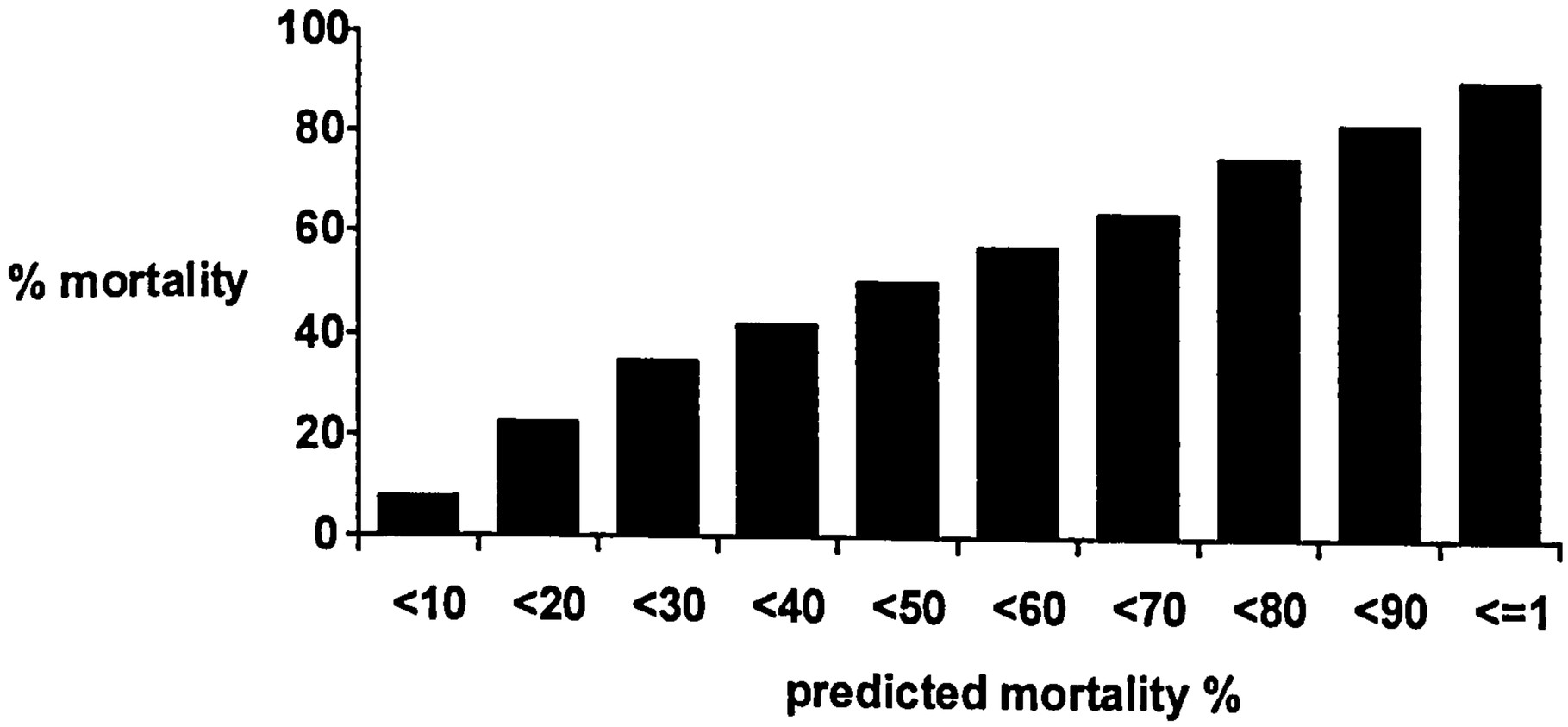
Predicted mortality

For all patients the number of deaths predicted by APACHE II was 3651 and the observed number was 4151 for an overall mortality ratio (observed hospital deaths/predicted deaths) of 1.137 (95% confidence interval 1.103 to 1.172). The mortality ratio for individual ICUs is shown in table 7.2. The result of the χ^2 test of Lemeshow and Hosmer (Lemeshow S and Hosmer DW. 1982) (sum of χ^2 = 180.9) implies that the APACHE II model does not accurately fit our data (table 7.4). In particular the observed number of deaths are greater than predicted for patients with a predicted risk of death (ROD) of < 0.6. Percentage observed mortality increased with increased predicted mortality (figure 7.2, table 7.4)]. However, as there were more ICU patients in the lower mortality bands the ***number*** of deaths remained broadly constant over the range of predicted mortality (figure 7.3, table 7.4). No obvious difference in

outcome was seen when comparing the mortality ratios of university with non-university hospitals and of ICUs with a high or low number of consultant ICU sessions per week (table 7.5).

Figure 7.2

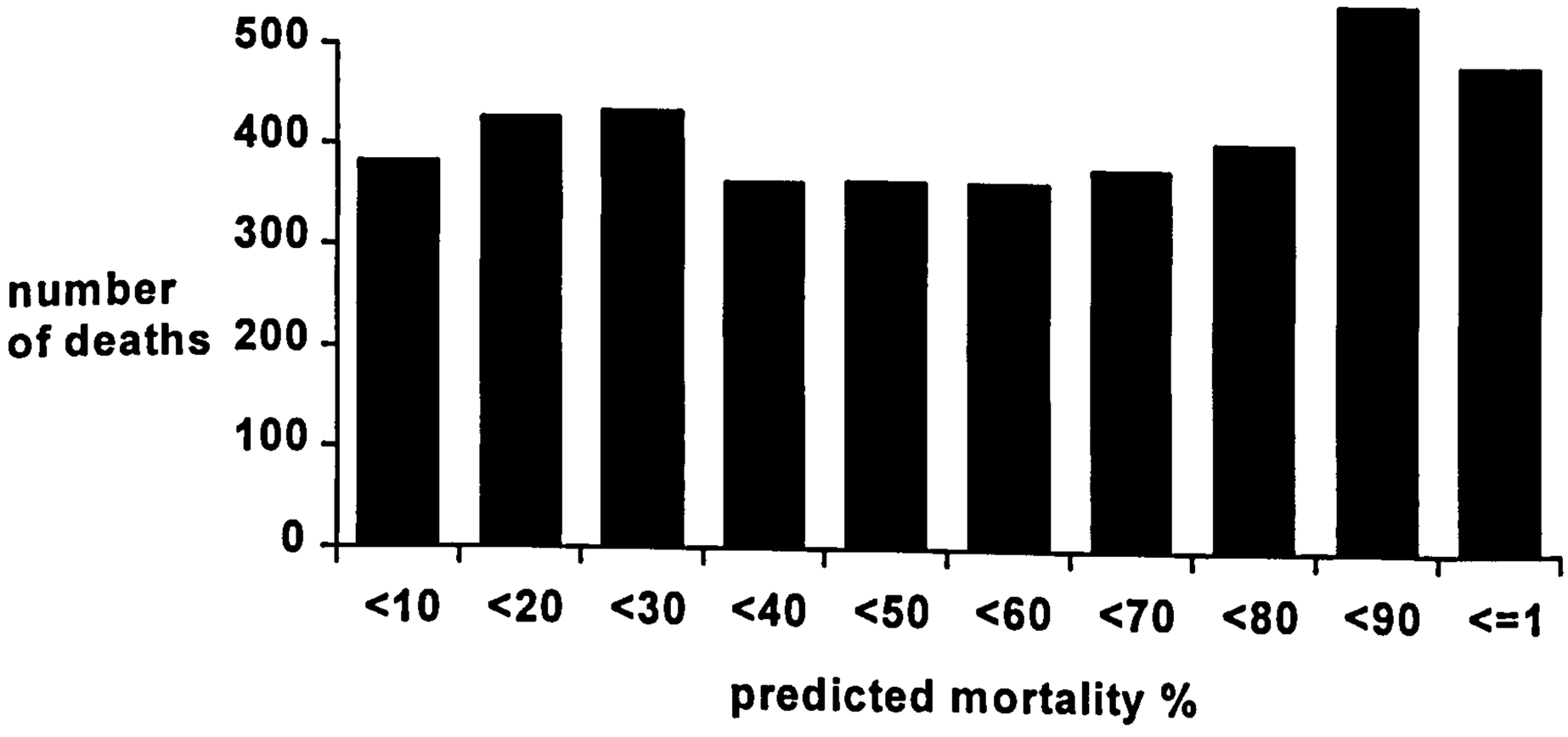
Percentage mortality by mortality predicted by APACHE II.



<10 = 0-10% predicted mortality, <20 = 10-20% predicted mortality etc.

Figure 7.3

Number of deaths by mortality predicted by APACHE II.



<10 = 0-10% predicted mortality, <20 = 10-20% predicted mortality etc.

Table 7.4

Goodness of fit for mortality predicted by APACHE II.

	survived number		died number		% deaths	% deaths
ROD	**observed**	**expected**	**observed**	**expected**	**hospital**	**after ICU**
<0.1	4647	4733.7	383	296.3	7.6	53.8
0.1 to < 0.2	1478	1623.0	427	282.0	22.4	49.2
0.2 to < 0.3	820	942.2	434	311.8	34.6	32.9
0.3 to < 0.4	509	566.7	363	305.3	41.6	32.8
0.4 to < 0.5	362	397.9	365	329.1	50.2	22.7
0.5 to < 0.6	270	283.6	363	349.4	57.3	23.7
0.6 to < 0.7	213	204.6	378	386.4	64.0	21.2
0.7 to < 0.8	136	135.4	406	406.6	74.9	20.7
0.8 to < 0.9	124	99.2	547	571.8	81.5	13.2
0.9 to ≤ 1.0	52	30.4	485	506.6	90.3	8.2
Total	**8611**	**9111**	**4151**	**3651**	**32.5**	**27.1**

Sum of χ^2 = 180.9, significantly different (p<0.001) from null hypothesis.

ROD = risk of death predicted with APACHE II; < 0.1 = 0% to < 10% predicted mortality band, 0.1 to < 0.2 = 10% to < 20% predicted mortality band etc., observed = number of hospital survivors or deaths, expected = number of hospital survivors or deaths predicted by APACHE II, % deaths hospital = % of ICU patients who died during their hospital admission, % deaths after ICU = % of hospital deaths of ICU patients that occurred after discharge from their first ICU admission.

Table 7.5

Outcome of ICU admissions comparing university with non-university hospitals and ICUs with a high or low number of consultant ICU sessions per week.

	number	**% deaths**	**% deaths after ICU**	**ROD**	**MR**
university	4822	31.3	29.4	0.264	1.19
non-university	7940	33.3	25.7	0.299	1.11
>= 9 sessions *	6943	32.8	27.3	0.286	1.15
< 9 sessions	5819	32.2	26.8	0.287	1.12

number = number of admissions, % deaths = = % of ICU patients who died during their hospital admission, % deaths after ICU = % of hospital deaths of ICU patients that occurred after discharge from their first ICU admission, ROD = risk of death predicted with APACHE II, MR = mortality ratio (observed hospital deaths/predicted deaths), university = teaching/university hospital, non-university = district general hospital/non-university hospital; one session approximates to one half day per week of consultant "intensivist" time dedicated to the ICU. (*the university ICU with < 9 sessions has been grouped with those with >= 9 sessions as it is run as a satellite ICU from the main university ICU by a single medical team).

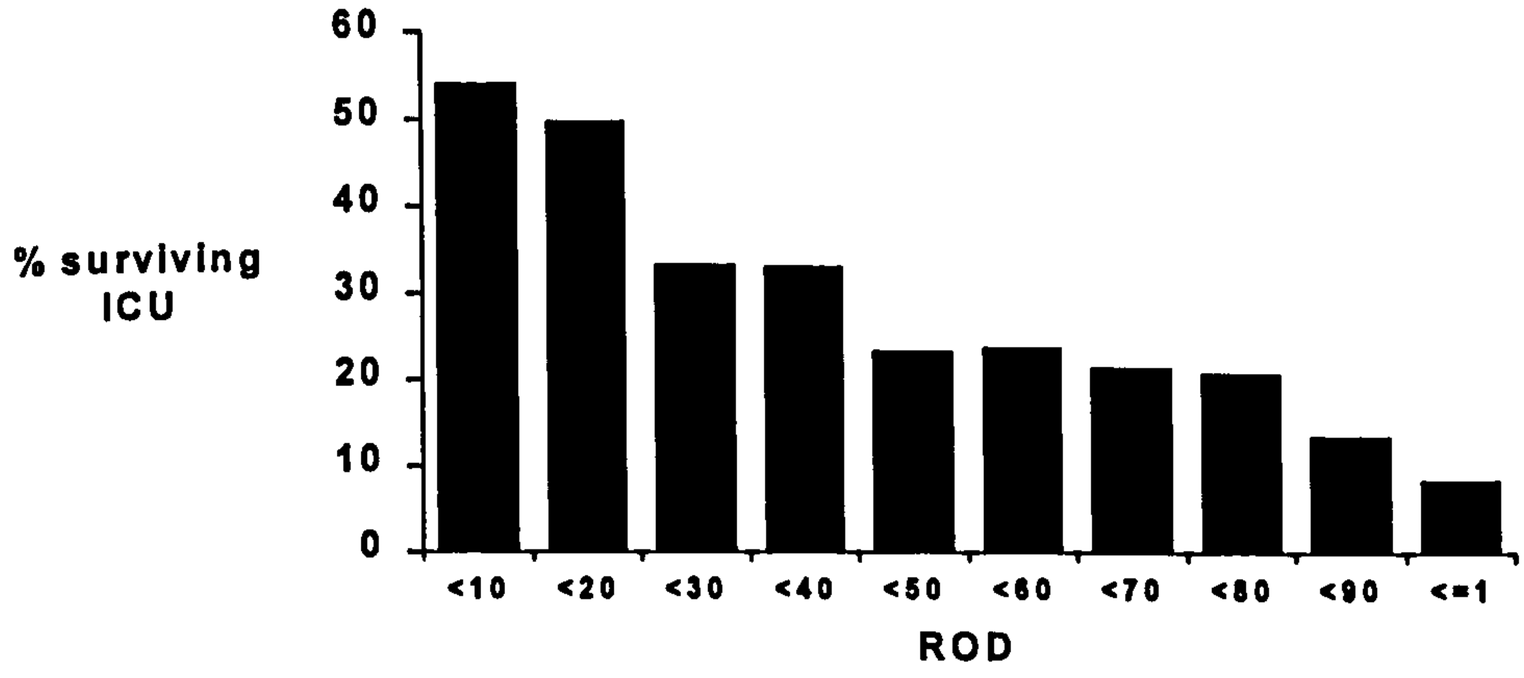
Deaths in patients surviving their first ICU admission

Some 27.1% (1123 patients) of all ICU deaths took place after the patients had survived to be discharged from ICU (table 7.4).

There were 6935 patients (54.3% of admissions) with a ROD less than 0.2 of whom 11.7% died. The majority of these deaths (51.5%) took place after patients were discharged from ICU (figure 7.4, table 7.4). In these relatively low risk patients, compared with those who died in ICU, those who died after ICU discharge stayed a significantly shorter time in the ICU (average 3.82 days compared to 6.48 days), were older with an average age 64.3 years (SD 17.0) versus 58.2 years (SD18.2), and a lower percentage (6.7% versus 16.5%) had a GCS of 8 or less. The percentage admitted to ICU following CPR was similar, 4.8% compared to 5.8%, and there was no difference in predicted ROD (average 0.103 versus 0.109). The number of deaths and the percentage of deaths that occurred in hospital after the first ICU admission are shown in table 7.6 for admission categories with at least 20 of these low risk patients who died in hospital.

Figure 7.4

Percentage of patients who die after surviving to leave ICU by predicted mortality.



<10 = 0-10% predicted mortality, <20 = 10-20% predicted mortality etc.

Table 7.6

ICU admission categories and percentage of deaths after first ICU admission for patients with a predicted risk of death (ROD) of < 0.2 who died in hospital.

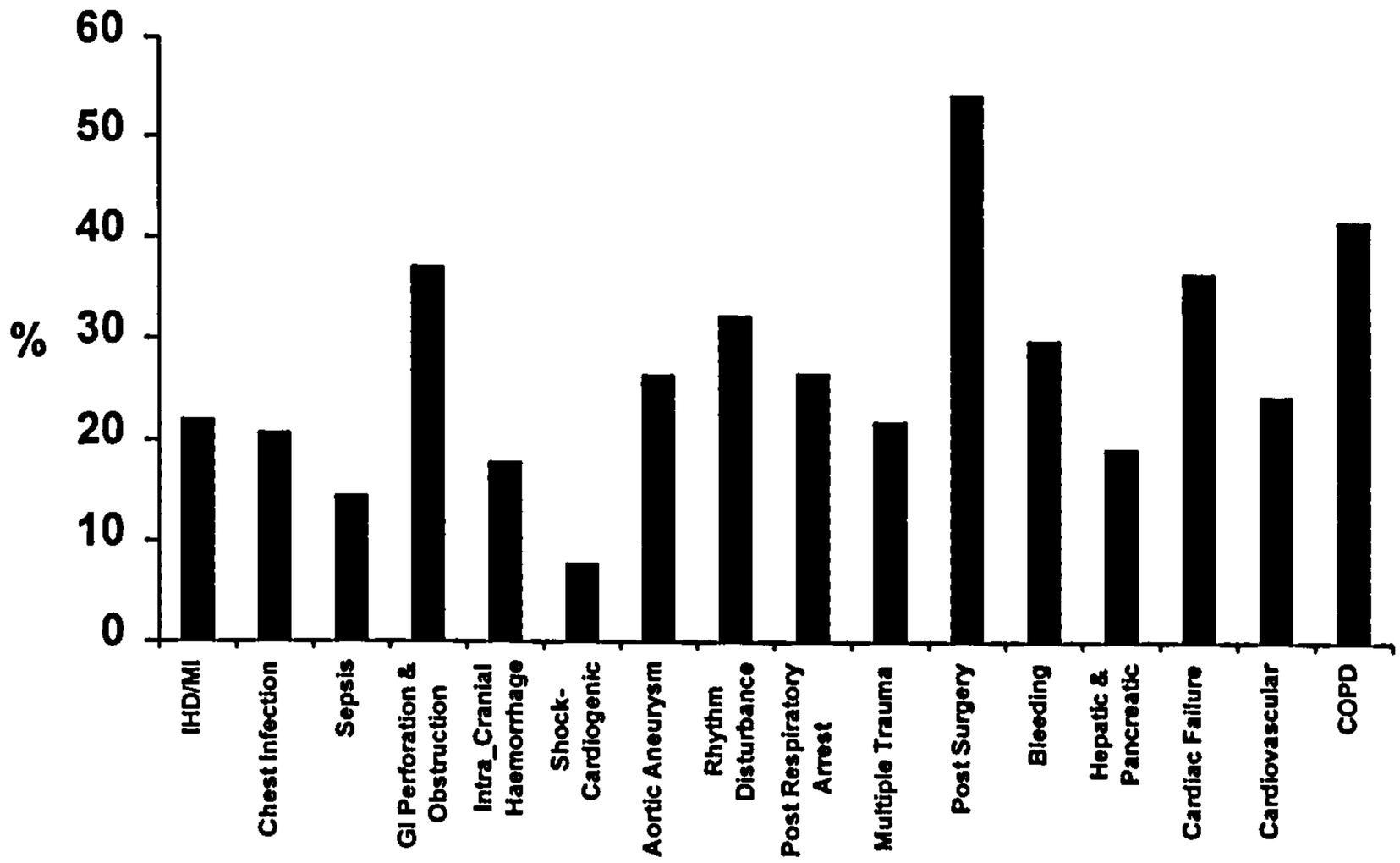
admission category	No. patients	% deaths after ICU
overdose	24	20.8
multiple trauma	42	31.0
ischaemic heart disease/MI	76	43.4
pulmonary infection	57	43.9
intracranial hemorrhage	22	45.5
respiratory	24	45.8
aortic aneurysm	71	47.9
GI hemorrhage	20	50.0
rhythm disturbance	47	59.6
congestive cardiac failure	24	62.5
GI neoplasm	32	65.6
perforation/obstruction	21	66.7
postoperative insufficiency	35	77.1
respiratory observation	62	77.4

Only admission categories are included which contain more than 20 patients with a ROD of < 0.2 who died in hospital (this encompasses 557 (68.8%) of the 810 patients fulfilling this criteria). No. patients = number of patients, % deaths after ICU= % of patients who died in hospital after their first ICU admission, MI = myocardial infarction, GI = gastrointestinal.

The percentage of patients dying after surviving a first ICU admission decreased as the predicted ROD increased (figure 7.4, table 7.4). As we excluded from analysis all ICU admissions apart from the first, patients who were discharged alive from ICU and subsequently died may have been re-admitted to ICU at a later date. There was a wide range by admission category in the percentage of patients who died in hospital after surviving a first ICU admission (fig 7.5). Of interest is the fact that over 50% of the deaths in patients admitted to ICU under the category of postoperative insufficiency occurred after ICU discharge. This group does not include patients admitted after aortic aneurysm surgery where some 27% of deaths took place after the first ICU admission.

Figure 7.5

Percentage of non-survivors by ICU admission category who survived their initial ICU admission to die later during the same hospital admission.



Only reasons for admission with the greatest number of patients are included. This encompasses 75% of non-survivors. (IHD = ischaemic heart disease; MI = myocardial infarction; GI = gastrointestinal; COPD = chronic obstructive pulmonary disease).

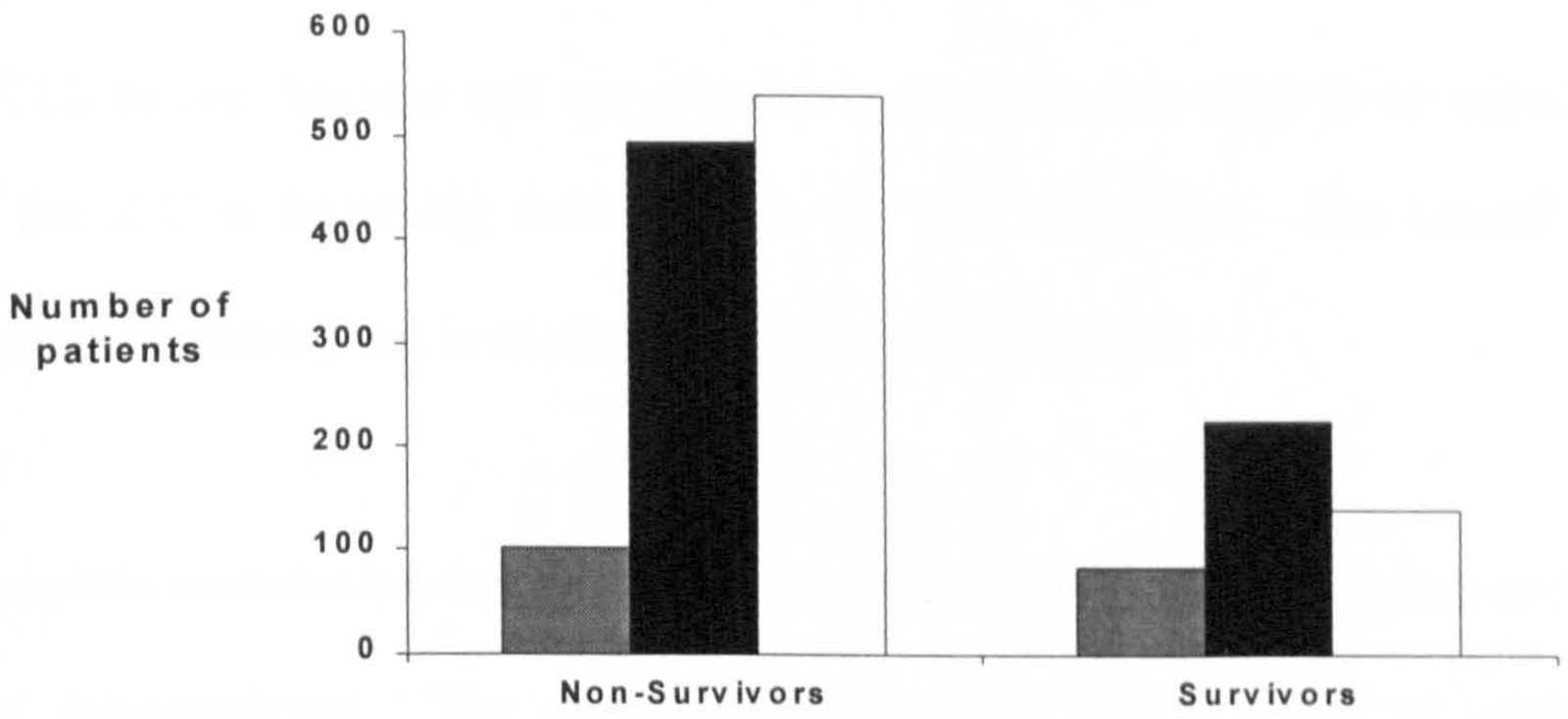
Deaths after cardiopulmonary resuscitation (CPR)

Of patients admitted after CPR, 71% died and this constituted 30% of all deaths. Relatively few patients under the age of 45 were admitted following CPR. Percentage mortality increased by increasing age grouping from 51% in those aged 16-30, to 79% in those aged greater than 75. After 2 days in ICU 70% of non-survivors following CPR had died with 90% dying within 8 days. Although 70% of survivors following CPR were discharged within 4 days, by 10 days 13% of patients who were eventually discharged alive from hospital were still in the ICU. Although the number of patients admitted from the operating room/recovery after CPR was relatively small, mortality

was 55.2%. Many more patients were admitted after CPR from the emergency room or the ward with 68.7% and 79.5% mortality respectively (fig 7.6).

Figure 7.6

Pre-ICU location and outcome for patients admitted to ICU after cardiopulmonary resuscitation (CPR).



Operating room/recovery, grey filled bars; emergency room, black filled bars; ward, open bars.

Patients with ICU admission of longer than 2 days

34.2% of patients were in the ICU for more than 2 days but accounted for 80.75% of total bed days. For these patients the average ROD was 0.28 for survivors and 0.50 for non-survivors. Overall ICU mortality for these patients was 39.8%. Survivors with an ICU stay of more than two days were younger (average age 54 years) than non-survivors (average 64 years) (highly significant difference $p<0.01$). Patients admitted after CPR who were in the ICU for more than two days had a mortality of 63.1% compared to 35.6% for those who did not arrest.

Discussion

Our analysis was based upon a subset consisting of nearly 55% of ICU admissions for the time period in our database. Almost all the exclusions (cardiac surgery, burns, less than 16 years of age, repeat ICU admissions, unknown outcome) were made in order to fulfill the criteria for the APACHE II risk stratification system. Also excluded were 870 admissions (3.7% of the database) from 9 ICUs who, at the time the data was analyzed, had each contributed fewer than 300 admissions to the database. We continue to recruit new ICUs to our database and our experience suggests that there is an initial period when the ICU is becoming familiar with the data collection. The cut-off of 300 admissions is arbitrary but is an attempt to allow for this effect.

The hospitals contributing data are a mixture of university/teaching hospitals and district general (non-teaching). The study period coincided with a period of considerable change in the provision of health care in the region. The number of intensive care and hospital beds were not constant over this period, although the numbers given in table 7.1 provide an indication of the size of the hospital and the provision of intensive care resources. The United Kingdom recommendation that 1-2% of acute hospital beds be ICU beds dates from the 1970s (Intensive Therapy Unit NHS Estates. 1992) and is widely recognized to be inadequate for most hospitals. The number of intensive care consultant sessions indicates the degree of senior medical involvement in running the ICU. One session approximates to one half day per week of consultant "intensivist" time dedicated to the ICU. In the United Kingdom, the Intensive Care Society recommends that the minimum weekly allocation of consultant sessions to an ICU of 4 or more beds should be 15 to cover daytime and out-of-hours commitments (Intensive Care Society. 1997). A minimum of 7 consultant fixed daytime sessions dedicated to the

ICU is required for training recognition. All the ICUs are also staffed by doctors receiving training in intensive care. Most of these doctors are anaesthetists on rotation. There is considerable variation between and within ICUs in the experience and training of these doctors and the amount of supervision and responsibility they are given.

The method of data collection, training and data validation is designed to minimize errors (Goldhill DR et al. 1993). Once entered correctly onto the form the data is read accurately into the computer. The percentage of errors is comparable to those reported in other studies (Goldhill DR and Withington PS. 1996a). Although information on the accuracy of the data is not available from other contributing ICUs it is likely to be best for objective information such as patient location before ICU, incidence of CPR before ICU, ICU stay and mortality, which are used to support the main themes of this part of the thesis. The admission categories are the primary reason for the patient's transfer to the ICU determined at the time of admission. Only one category is selected and there is inevitably some overlap and simplification in the patient with multiple problems. Patients may develop life threatening complications, such as sepsis, after ICU admission.

There is a wide difference in outcome for patients admitted to different ICUs even adjusting for differences in casemix and severity of illness using risk adjustment methods such as APACHE II (Knaus WA et al. 1986, Rowan KM et al. 1993b, Knaus WA et al. 1993, Wong DT et al. 1995, Bastos PG et al. 1996b, Moreno R. 1997). Although there may be limitations in the ability of APACHE II to identify differences between ICU (Goldhill DR and Withington PS. 1996a, Goldhill DR and Withington PS. 1996b) it has been suggested that these differences, in part, may be related to the structure and process of the delivery of ICU care between the ICU (Bastos PG et al.

1996b, Zimmerman JE et al. 1993b, Zimmerman JE et al. 1993a). This consideration should be extended to encompass the care patients receive before ICU admission and after discharge.

Of all the patients who died, 30.3% were admitted following CPR. A further 21.7% of patients who did not receive CPR before ICU admission died after discharge from their first ICU admission. In addition 25.8% of deaths occurred on the ICU no more than 2 days after ICU admission in patients who did not receive CPR before admission. Altogether this adds up to 78% of ICU deaths. For many patients in these categories the ICU admission may be essential in order to allow the possibility of recovery but ICU care may make little difference to outcome.

The widely perceived shortage of intensive care beds in the United Kingdom (Vincent JL. 1990) means that it is often difficult to admit seriously ill patients. This is supported by evidence on mortality of ICU patients. The average ROD was 0.286 for our patients and this compares with 0.272 in other British data using APACHE II (Rowan KM et al. 1993b). One study from the United States reported a ROD of 0.198 (Knaus WA et al. 1986). In another United States study the average ROD was 0.188 for teaching and 0.151 for non-teaching hospitals (Zimmerman JE et al. 1993b). In this paper by Zimmerman et al only 4 out of 37 ICUs reported an average ROD of more than 0.25 whereas only 2 out of our 15 ICU had an average ROD of less than this value. A Canadian study has reported a ROD of 0.247 (Wong DT et al. 1995) and a ROD of 0.20 was calculated for a group of Brazilian ICUs (Bastos PG et al. 1996b).

In the United Kingdom the overwhelming majority of intensive care units are run by doctors who have anesthesia as their primary specialty, although several in our database are under the direction of physicians. The university hospital ICUs tend to be bigger and accept more patients requiring specialized care than other ICUs. There is usually little difference in the clinical management, staffing, and consultant experience on the ICUs between the two types of hospital. There are, at present, very few full-time "intensivists". Although there is some evidence from other systems that the introduction of a full-time director may contribute to a decrease in intensive care mortality (Manthous CA et al. 1997, Brown JJ and Sullivan G. 1989, Pollack MM et al. 1988) this was not reflected in our data. Differences in ICU management, training, staffing, patients selection and delivery of care may provide some explanation for this. However, considering our hypothesis that many of the potentially preventable ICU deaths are determined by events taking place outside of the intensive care unit, it is not surprising that consultant input and type of hospital have no discernible effect on ICU outcome.

By the time patients reach the ICU in the United Kingdom it may be possible to identify those with a high risk of death but it may be too late to do much to influence the outcome of those who die within the first day or two of admission. Such patients will include some with brain damage after trauma or hypoxia, with terminal cancer or leukaemia, and with end stage respiratory failure. Many of these patients will have had underlying pathology and physiology too deranged to respond to a short period of intensive care therapy. Much intensive care research is focused on treatments directed at sepsis, acute respiratory distress syndrome (ARDS) and multiple organ failure, problems that occur primarily in the long stay ICU patient. To appreciably decrease early ICU mortality it may be necessary to intervene before admission to the ICU. There is some

supporting evidence in high risk surgical patients showing that optimisation of physiological values before surgery and ICU admission may decrease mortality (Heyland DK et al. 1996).

Patients admitted to the ICU following CPR have a low chance of survival. This particularly applies to patients who require resuscitation on the ward (Bialecki L and Woodward RS. 1995). These hospital inpatients are obviously at risk and it may be possible to identify them and intervene before the acute event requiring CPR (Franklin C and Mathew J. 1994). It remains to be seen whether early intervention, such as with an intensive care intervention team (Lee A et al. 1995), will increase their survival but it is clear that their prognosis is poor after the CPR. Although it is likely that there will be relatively few patients admitted from the emergency room in whom the need for CPR can be anticipated and prevented, it is reasonable to question whether intensive care admission is appropriate for some of these patients, for example those with an out of hospital traumatic arrest (Rosemurgy AS et al. 1993), where pre-hospital spontaneous circulation was not established or after an unwitnessed arrest resulting in electro-mechanical dissociation (EMD) (Herlitz J et al. 1995, Kellerman AL et al. 1993). Bystander resuscitation and paramedic response and training are likely to be more important than intensive care in improving outcome for these patients (Grub NR et al. 1995, Heller RF et al. 1995).

It should be noted that early intervention may improve survival which may not be reflected in the mortality ratio (observed hospital mortality/predicted mortality). Observed mortality may decrease but, as mortality prediction for ICU patients is based on the patients' status shortly before or on admission to the ICU, predicted mortality will

also fall as physiological abnormalities and arrest are prevented. Case mix adjustment systems such as APACHE II are therefore likely to be unable to distinguish hospitals which provide good care before ICU from those that do not.

Over a quarter of the patients died following discharge from the ICU. This included about 50% of those patients with a low predicted mortality (ROD < 0.2). Many of these low risk patients who died after ICU discharge were admitted to the ICU following surgery and this is reflected in the finding that over half of the patients admitted under the category of postoperative insufficiency died after ICU discharge. As a rule surgery should be undertaken in patients with a reasonable chance of survival and further studies would be interesting to investigate the causes of death in these postoperative patients. We only looked at patients' first ICU admission and those who eventually died may have been readmitted later in their hospital stay.

In the United Kingdom there is great pressure on ICU beds and relatively little provision of high dependency care (Ryan DW. 1996, Bion J. 1995b). It is widely felt that many patients are discharged too early, and often sent to a ward with little or no additional monitoring or care. The fact that so many deaths occur after ICU discharge, and that 9.8% of admissions in the database are second or subsequent admissions, supports this impression. Further studies support this with the percentage of deaths occurring after ICU discharge at 35.4% in the United Kingdom (Rowan KM et al. 1993b), 23.4% in Portugal (Moreno R. 1997) and 14.7% in Brazil (Bastos PG et al. 1996b). A Scottish study reported that 31% of deaths were on the wards after ICU discharge and, although 25.5% of the ward deaths were anticipated, in over 20% of them the patients were expected to survive (Wallis CB et al. 1997). The authors concluded that some of the

deaths may have been preventable with further intensive care or improved ward care. A proportion of patients will be discharged from ICU with do-not-resuscitate orders or their equivalent. We do not have any information on the percentage of our patients in this category.

Percentage hospital mortality increased with the ROD calculated using APACHE II (Knaus WA et al. 1985). Table 7.4 clearly illustrates the excess observed mortality compared to predicted in patients in the lower ROD bands. Reasons why our data may not fit the APACHE II model include differences in case mix, lead time bias and problems with data collection and accuracy (Goldhill DR and Withington PS. 1996a, Goldhill DR and Withington PS. 1996b, Goldhill DR et al. 1999). We have previously demonstrated the considerable effect of small changes in APACHE II score on predicted mortality and this effect is most marked for admissions with a low predicted mortality (Goldhill DR and Withington PS. 1996b). In a previous United Kingdom study the American APACHE II equation did not adjust uniformly when the data was divided into certain subgroups (Rowan KM et al. 1993b). Caution must therefore be exercised before concluding that there really is an excess mortality for the lower risk admissions. Because there were fewer patients in the higher risk groups there were approximately as many patients who died in lower predicted mortality bands as in higher bands. It is likely, although unproved, that a considerable number of patients who died with a relatively low predicted mortality had the potential to survive. As APACHE II is determined, in part, by age and chronic health, many patients with low predicted mortality are likely to be relatively young, have no pre-existing disease, and may be able to return to productive life if they survive. As already noted many of these patients who died did so after ICU discharge. These relatively low risk patients are an obvious target

for decreasing ICU mortality and are more likely to pay dividends than high predicted mortality admissions.

Our analysis provides little hope for early identification of long stay ICU patients unlikely to survive. Although long stay patients consumed the majority of resources our analysis could not clearly differentiate early between survivors and non-survivors and this is supported by other studies (Niskanen M et al. 1991, Tuchschmidt JA and Mecher CE. 1994, Kaufmann MA et al. 1992). Daily assessment, taking account of changes in the patient's physiology and treatment, may provide a means for earlier detection of poor outcome (Chang RW et al. 1988). One way of decreasing the cost of ICU is to refuse admission to patients for whom there is no benefit (Bion J. 1995b). Consultation and planning before considering ICU may minimize the number of such admissions.

Mortality predicted with APACHE II is based upon physiological abnormality, age, chronic health, previous surgery and reason for ICU admission (Knaus WA et al. 1985). Age and chronic health cannot be altered but early identification of patients at risk, both before admission and after discharge from the ICU, may allow treatment to prevent some of the physiological abnormalities contributing to the APACHE II score. Such intervention may also help prevent a pre-ICU arrest in ward patients. As most non-survivors died within a few days of ICU admission, intervention before admission may be the most effective way of decreasing ICU mortality. Intervention could include improving perioperative management, identifying high risk ward patients likely to require ICU admission and identifying patients for whom ICU admission would be inappropriate (Bion J. 1995b, Bellamy PE and Oye RK. 1987). Research and resources may be best directed at patients who die despite a relatively low predicted mortality.

Although these patients are a small percentage of the low risk admissions they constitute a large number of ICU deaths and may be more susceptible to intervention with a better prospect of future quality of life than high risk patients. Many patients die after discharge from ICU and this mortality may be decreased by minimizing inappropriately early discharge to the ward, by the provision of high dependency and step down units (Franklin CM et al. 1988), and by continuing advice and follow up by the ICU team after the patient has been discharged.

8. Initiatives arising out of questions posed by the intensive care data

Introduction

Analysis of the ICARUS data indicated patient groups where changes in management may be expected to improve outcome.

One of these groups was postoperative patients. Although only a minority of elective and emergency surgical patients are admitted to the ICU, a high percentage of those who die do so after they have been discharged from the ICU. The intensive care literature teaches us that increased mortality is associated with deranged physiology. Studies involving postoperative patients describe patterns of abnormal oxygenation, cardiac rate and rhythm and other physiological abnormalities. With appropriate management many of these physiological values could be maintained within the 'normal' range and this may improve outcome. This led me to think about ways in which the care of postoperative patients could be improved and resulted in the following section describing the concept of the postoperative care team (Goldhill DR. 1997a).

The ICARUS data also revealed the importance of patients admitted from the hospital wards in the ICU mortality figures. The study on physiological values in patients admitted to ICU from the wards provided information on the physiological abnormalities associated with patients shortly before ICU admission. This data was used to define criteria likely to identify critically ill patients on the wards. A patient at risk team (PART) was introduced to help in the management of these patients. Information collected while the PART was active was used to see if the physiological

criteria for alerting the team were of any practical use. A report on the work of the team and its impact on ICU admissions provides information which may be useful when devising systems for delivering care in order to improve outcome for these patients.

The Postoperative Care Team- The next challenge for anaesthetists?

The 1992/1993 National Confidential Enquiry into Perioperative Deaths (NCEPOD) (Campling EA et al. 1995) tells us that operating theatres are safe places for healthy patients undergoing uncomplicated surgery. An investigation such as NCEPOD records the use of monitoring, the availability of facilities such as a recovery area and ICU, and the experience of the doctors caring for the patient. Such information helps us to identify if the means to deliver care are appropriate but does not tell us if the monitoring, facilities, doctors and nurses are used to provide the best possible care.

The fact that nearly 65% of postoperative patients reported in NCEPOD died 3 days or longer after surgery with many of the deaths taking place on a ward does not absolve the anaesthetist from responsibility for the deaths. A high percentage of those who died had a cardiac or respiratory complication, renal failure or infection, and a proportion of these complications may be preventable.

In the operating theatre anaesthetised patients are constantly supervised by an anaesthetist who has at their disposal a range of excellent anaesthetic agents, many proven techniques and an array of sophisticated and reliable monitors and alarms.

Great care is taken to maintain cardiovascular stability, adequate oxygenation, analgesia and fluid balance. Intraoperative deaths are uncommon. For healthy patients undergoing a relatively brief procedure with few postoperative sequelae, recovery is swift and major postoperative problems rare. Selected patients will be admitted to the ICU or high dependency unit (HDU) after major surgery so that a high quality of care is continued into the postoperative period. For most patients the transition from anaesthetised state until protective reflexes recover and cardiovascular stability is achieved is supervised in the postoperative recovery area. Once returned to the ward from the recovery area or ICU/HDU the patient is no longer as closely supervised or monitored and this may be the time when many patients are now most at risk.

Preoperative preparation and a high standard of anaesthetic care are essential as they affect postoperative events (Berlauk JF et al. 1991, Boyd O et al. 1993, Campos AC and Meguid MM. 1992, Nomori H et al. 1994). Physiological variables routinely measured in the perioperative period may not be sensitive enough for early detection of an adverse outcome and by the time surgery has finished it may be too late to substantially alter outcome for some patients (Mythen MG and Webb AR. 1994). On the other hand aggressive postoperative optimisation of physiological values has been shown to decrease mortality in a selected group of ICU patients (Shoemaker WC et al. 1988) and acute confusional states in elderly patients after femoral neck surgery (Gustafson Y. 1991). The principle of proactive therapy to prevent complications could be widened to a larger group of postoperative patients.

In the postoperative period renal, hepatic, gastrointestinal and other organ function may be at risk because of inadequate perfusion and oxygen delivery. Breathing may be limited because of pain or oversedation thus contributing to chest infection or episodes of hypoxaemia for several days after surgery (Catley DM et al. 1985, Reeder MK et al. 1992). Cardiac ischaemia may result from hypertension, tachycardia or hypoxaemia (Reeder MK et al. 1991). Deep venous thrombosis may be more likely with poor analgesia limiting early mobilisation and inadequate fluid replacement contributing to venous stasis. The incidence of wound infection and bowel anastamotic breakdown are likely also to be related, in part, to postoperative factors. Many of these adverse events do not manifest for several days after surgery. Some, such as silent ischaemia, deep venous thrombosis or minor renal or hepatic dysfunction, may not be detected, whereas others may only be reflected in a longer than necessary postoperative stay in hospital.

In high risk patients optimisation of physiological values should be achieved before surgery and it should be possible to declare targets to be achieved in the postoperative period. These would certainly include an oxygen saturation of greater than 90%, the absence of episodes of significant ST segment depression on the electrocardiogram (ECG), adequate and appropriate cardiac output, renal output and fluid replacement, excellent analgesia and the absence of oversedation. The techniques exist for appropriate monitoring and management.

It is possible to imagine a ward, where effective analgesia is available to all patients after surgery. Particular emphasis would be placed on fluid management, guided by established critical care techniques. Pulmonary exercises may decrease the incidence

of respiratory complications (Roukema JA et al. 1988). Oxygen therapy is effective at preventing hypoxaemia (Nolan KM et al. 1992) and would be titrated against oxygen saturation as measured by pulse oximetry. Continuous ECG monitoring with computer-assisted processing for detecting abnormalities would provide early warning of dysrhythmias and ischaemia. Appropriate early nutrition would be encouraged (Moore FA et al. 1992) and measures taken to minimise the risk of infection (Greco D et al. 1991). Informed medical advice would be readily available to manage and guide therapy. All of the above should be available on a routine surgical ward but experience suggests that this is rarely the case.

The NCEPOD rightly identifies a "substantial shortfall in critical services" and an HDU should fulfil all of the functions described above. Although not as costly as an ICU the HDU is nonetheless an expensive option that is unlikely to be available to the majority of postoperative inpatients, particularly beyond the first few hours after surgery. The acute pain care team has evolved to look after the analgesia needs of the postoperative patient (Commission on the provision of surgical services and The Royal College of Surgeons of England and the College of Anaesthetists. 1990). It may be time to widen the concept to encompass a general postoperative care team to provide the standards of care described above. Regular postoperative care rounds and a team of postoperative care nurses should be able to support nursing staff on the surgical ward and provide additional expertise, equipment and staff to assist in the care of the majority of postoperative inpatients.

It remains to be proven if a comprehensive system of continuing postoperative care would decrease morbidity and mortality, provide greater comfort and satisfaction, or

allow patients to be safely discharged at an earlier time than is routine at present. Anaesthetists have already extended their care of the postoperative patient into the ICU and acute pain service. If improvements in outcome following anaesthesia and surgery are to continue it may be necessary to take on the challenge of general postoperative care.

Physiological values and procedures in the 24 hours before ICU admission from the wards.

Introduction.

Analysis of ICARUS data showed that the largest number of non-survivors admitted to ICU were from the hospital wards (Goldhill DR and Sumner A. 1998). These patients had a higher percentage mortality than patients admitted from the operating theatres/recovery area or the accident and emergency department (A&E). Cardiopulmonary resuscitation (CPR) preceded ICU admission in approximately 24% of these patients. If ICU mortality rates are to be improved the hospital inpatient is an obvious target for intervention.

Previous studies have shown that in-hospital cardiac arrests are commonly preceded by physiological abnormalities (Franklin C and Mathew J. 1994, Schein RM et al. 1990, George ALJ et al. 1989). If admission to the ICU, or cardiac or respiratory arrest, are preceded by specific physiological derangement, then early identification of these "high-risk" hospital inpatients may be possible. This provides the opportunity for intervention with the aim of improving survival.

I hypothesised that patients admitted to ICU from the wards were often in hospital and seriously ill for some time before ICU admission. By the time they are finally admitted to ICU they may be so sick that they quickly die or require a prolonged stay in ICU in order to recover. If these patients can be recognised and treated earlier it may be possible to decrease mortality, as well as the ICU stay for survivors. This study was undertaken to describe the reasons for ICU admission in hospital inpatients and to identify physiological values and interventions likely to be associated with a patient at risk. This data has the potential to be used to formulate objective criteria identifying ward patients who require input from intensive care physicians.

Methods.

All ICU admissions from the wards at The Royal London Hospital over a 13 month period from May 1995 were examined prospectively. Patients were included in the study if they had been in hospital for at least 24 hours and had not undergone surgery in the 24 hours immediately before ICU admission.

On admission to the ICU available written information on these patients was examined including medical, nursing and physiotherapy notes. For each patient a record was made of their age, date and time of hospital admission, date and time of ICU admission, reason for ICU admission and details of chronic health problems, previous surgery or intensive care.

For the 24 hours immediately before ICU admission the highest and lowest recorded values of ten physiological variables were noted, (temperature, mean arterial blood

pressure, heart rate, respiratory rate, pH, sodium, potassium, creatinine, haemoglobin and white cell count), the Glasgow Coma Score (GCS), arterial blood gas results (PaO_2 and $PaCO_2$) and oxygen saturation (SpO_2). The patient's urine output and any indication of central nervous system depression were also noted. A record was made if physiotherapy, continuous positive airway pressure (CPAP), administration of oxygen, central venous (CVP) access/monitoring, oxygen saturation monitoring or cardiopulmonary resuscitation (CPR) was provided. If oxygen was administered but there was no record of the inspired concentration (FiO_2), this was assumed to be 40%.

The values for temperature, mean arterial blood pressure (MAP), heart rate, respiratory rate, GCS and SpO_2 were usually taken from nursing observation charts, with some results found in the medical or nursing history. The temperature was assumed to be a core value. The MAP was calculated as diastolic blood pressure (DBP) plus one-third of the difference between systolic (SBP) and DBP (MAP = DBP + (SBP-DBP)/3. The blood test results were commonly found in the medical history or in laboratory results charts. If results were not in the patient's notes the pathology computer was searched for samples logged into the laboratory within the relevant time period. In patients who received CPR, values recorded before the resuscitation were used in the analysis.

The 24 hours immediately before ICU admission were divided into three time periods: 0-6 hours, 6-12 hours and 12-24 hours before admission. Wherever possible physiological values and procedures/interventions were noted for each of the time periods.

Patients were divided into those with primarily an airway, breathing or circulatory reason for ICU admission. Patients admitted to ICU were grouped by time of day and day of week of admission.

The percentage of admissions with recordings of physiological values and interventions was calculated for the 24 hours before ICU admission and for each of the three time periods. The highest APACHE II points (Knaus WA et al. 1985) were calculated for each of the ten physiological variables, the GCS and for oxygenation (as defined in APACHE II) for the 24 hours before ICU admission. The GCS was only recorded if an accurate assessment could be made. Zero APACHE II points were awarded for values in the "normal" range. A maximum of four points were scored for each physiological variable, apart from the GCS which scored 15 minus the GCS and creatinine where points were doubled with acute renal failure. To determine if there was a physiological deterioration before ICU admission, APACHE II points for the variables were calculated for each of the three time periods in the 24 hours before ICU admission. This was only done where a value of the physiological variable was available from each time period for at least 50% of the admissions.

An APACHE II score was calculated for 24 hours before ICU admission by summating the highest points for each physiological value and adding points for age and chronic health problems (Knaus WA et al. 1985). An APACHE II score was also calculated for the 24 hours after ICU admission. We recorded how long the patients were in hospital before, during and after their ICU admission and whether they survived to leave ICU and hospital. A comparison was made of physiological values

and interventions between patients who did and did not receive CPR before ICU admission.

Categorical data was analysed with Chi square, with Yates' correction where applicable, and continuous data was evaluated with a Mann-Whitney or t-test. Statistical analysis with Chi square for trend was used to test the change in APACHE II points over the three time periods before ICU admission. APACHE II points were used as this allowed for worst values, both high and low, when examining for trends. In order to avoid multiple testing, statistical analysis was only performed if an inspection of the data suggested that there may be a difference.

Results.

During the period studied there were 923 admissions to the ICU. Of these admissions 105 were transfers from other hospitals, 406 from theatres/recovery, 244 from the A&E and 168 from the wards. Of the patients admitted from the wards 63 had been in hospital for less than 24 hours or had been readmitted to ICU within 24 hours of discharge, and 26 were admitted from the wards within 24 hours of surgery. The criteria for analysis was therefore fulfilled by the remaining 79 admissions from 76 patients, as three patients were each admitted twice.

Patients studied were in hospital a median of 10 days before ICU admission (range of 1 to 75 days; interquartile range 4 days to 23.5 days). Admissions were spread throughout the week with no obvious relationship to weekdays or weekends (table 8.1). Most admissions occurred during reasonable working hours.

Table 8.1

Day of week and time of ICU admissions from the wards.

day	Mon	Tue	Wed	Thur	Fri	Sat	Sun
%	14	18	20	6	15	13	14

time	00-<04	04-<08	08-<12	12-<16	16-<20	20-<24
%	16	4	25	20	16	18

% = percentage of admissions occurring on given day or within time period. time = time of admission so that 00-<04 =between midnight and before 4 a.m., 04-<08 = between 4 a.m. and before 8 a.m. etc.

The primary reasons for ICU admission are in table 8.2. The main event precipitating ICU admission has been categorised as airway, breathing or circulation. The percentage who received CPR is given for the three categories.

Table 8.2

Reason for ICU admission.

reason for ICU admission	number	CPR (%)	main precipitating event
Airway	6	2 (33%)	5 fitting 1 bit through endo-tracheal tube
Breathing	54	16 (30%)	23 infection/aspiration often with systemic disease 8 CNS depression - aspiration/apnoea/infection 6 respiratory failure 4 following trauma to chest or cervical spine 8 chest infection and immuno-compromised 3 muscle weakness 2 pulmonary embolus
Circulation	19	9 (47%)	7 sepsis/pancreatitis 5 hypovolaemia 7 ischaemia/cardiac failure

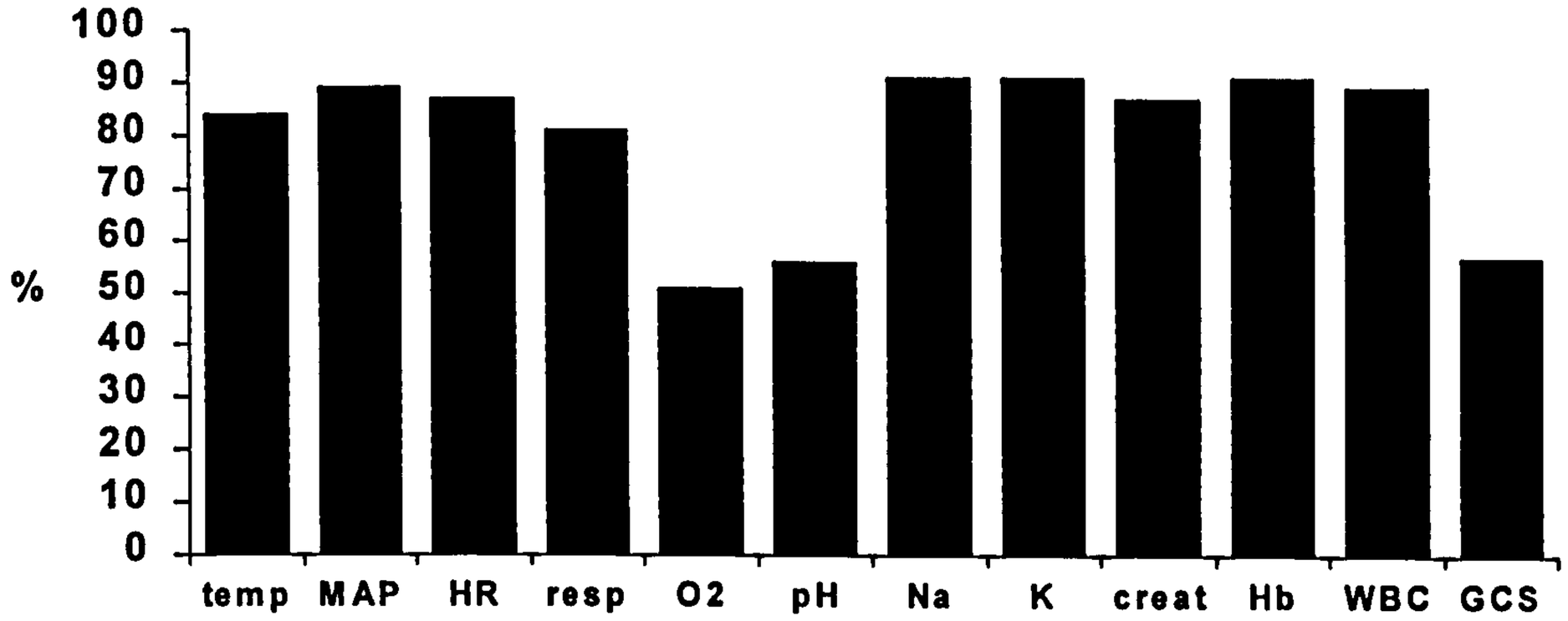
number = number of admissions, CPR (%) = number and percentage of admissions who received CPR before ICU admission

Serious chronic health problems were recorded using the definitions in APACHE II (Knaus WA et al. 1985). They were common, occurring in 47% of the 76 patients. The criteria for chronic health problems are specific and describe a severe restriction on activity or risk to life. Twenty one patients (28%) had undergone surgery during their hospital admission before the ICU admission studied. In addition to the ICU admissions studied, ten patients had a further admission excluded from investigation, six immediately following surgery and four within 24 hours of hospital admission. A further total of four ICU admissions in three patients included in the study occurred after the study period.

The percentage of admissions where a physiological value was available for the 24 hours before admission ranged from 51% for oxygenation to 91% for sodium, potassium and haemoglobin (figure 8.1). Although a blood test was usually performed at least once during the 24 hours before ICU admission, it was uncommon to have multiple results. Values of the routine observations, temperature, blood pressure, heart rate and respiratory rate, were available at sometime in the 24 hours before ICU for between 81% and 89% of admissions. The percentage of values available during the three time periods before admission are in table 8.3.

Figure 8.1.

Percentage of patients with physiological values recorded in the 24 hours before ICU admission.



temp = temperature; MAP = mean arterial blood pressure; HR = heart rate; resp = respiratory rate; O2 = arterial blood gas results allowing calculation of APACHE II oxygenation points; Na = sodium; K = potassium; creat = creatinine; Hb = haemoglobin; WBC = white cell count; GCS = Glasgow Coma Score.

Table 8.3

Percentage of admissions where the value of the physiological variable was recorded at 3 time periods before ICU admission.

physiological variable	12-24 hrs	6-12 hrs	0-6 hrs
temperature	71	56	59
MAP	75	70	76
heart rate	73	70	75
respiratory rate	65	59	65
oxygenation	16	18	43
pH	18	19	48
GCS	49	39	49

12-24 hrs/6-12 hrs/0-6 hrs = percentage of admissions with physiological value recorded at 12 to 24 hours, 6-12 hours or 0-6 hours before ICU admission; MAP = mean arterial blood pressure; GCS = Glasgow Coma Score.

Table 8.4 shows the APACHE II points based on the most extreme physiological values for the 24 hours before ICU admission. Some 80% of patients had values for heart rate, respiratory rate and oxygenation outside the 'normal' range thus scoring one or more APACHE II points (table 8.4, figure 8.2). Statistical analysis of the change in APACHE II points over the three time periods before ICU admission was performed on temperature, MAP, heart rate and respiratory rate as these were the only variables where more than 50% of values were available at all three time periods. Only respiratory rate showed a statistically significant increase in APACHE II points over time (p=0.003).

Table 8.4

Average APACHE II points and percentage by points scored for the 24 hours before ICU admission.

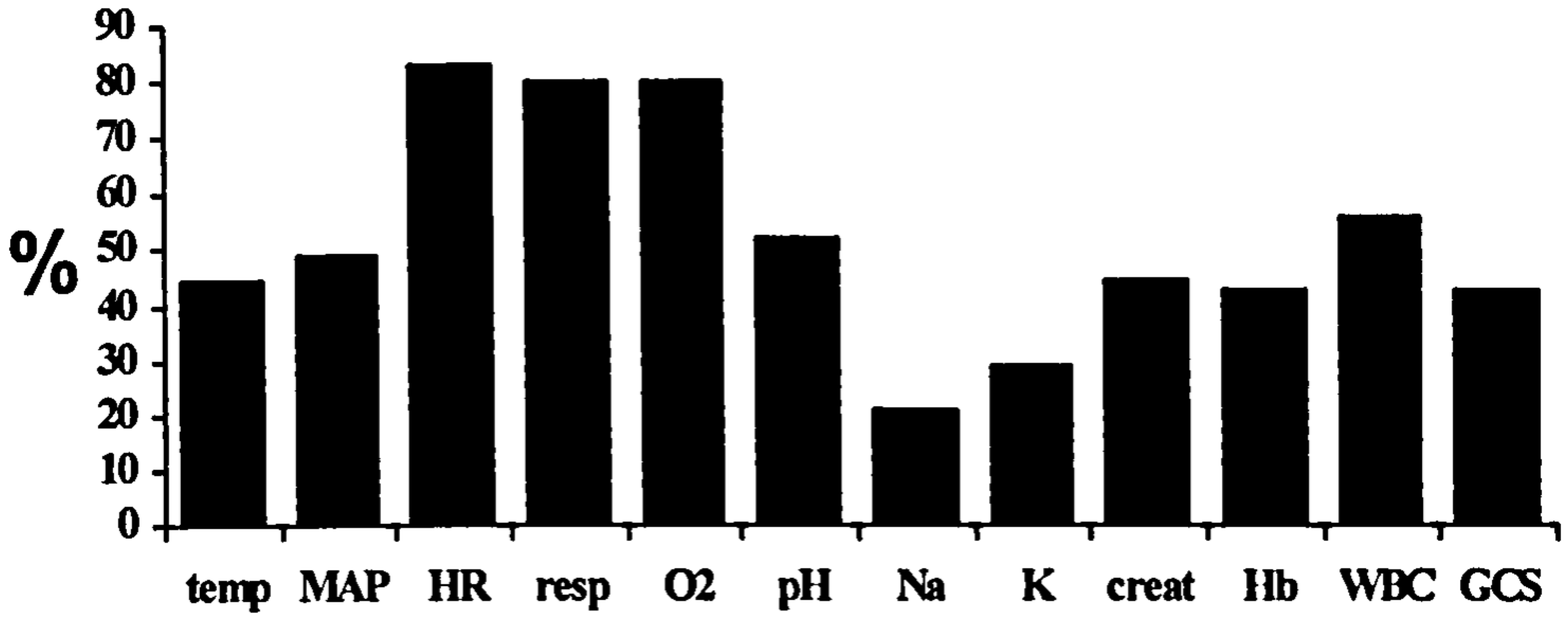
		% by points scored				
variable	**avg points**	**0**	**1**	**2**	**3**	**4**
temperature	0.77	55	29	2	15	0
MAP	1.04	51	0	44	1	3
heart rate	2.20	17	1	36	36	9
respiratory rate	2.05	20	25	3	33	19
oxygenation	2.52	20	13	13	5	50
pH	1.55	48	7	7	20	18
sodium	0.42	79	3	15	3	0
potassium	0.56	71	14	7	6	3
***creatinine**	2.04	55	0	14	10	20
haemoglobin	0.97	57	4	31	1	7
WBC	1.17	44	20	23	0	13

		GCS points range			
	avg points	**0**	**1-4**	**5-8**	**9-12**
GCS	4.22	57	4	7	33

avg points= average; 0 = % scoring 0 APACHE II points; 1 = % scoring 1 APACHE II point etc; GCS points range = percentage scoring 0 points, 1-4 points, 5-8 points or 9-12 points; MAP = mean arterial blood pressure; * creatinine points shown without effect of doubling in patients with acute renal failure WBC = white blood cell count; GCS = Glasgow Coma Score.

Figure 8.2

Percentage of patients with physiological values recorded in the 24 hours before ICU admission outside the 'normal' range (scoring 1 or more APACHE II points).



temp = temperature; MAP = mean arterial blood pressure; HR = heart rate; resp = respiratory rate; O2 = arterial blood gas results allowing calculation of APACHE II oxygenation points; Na = sodium; K = potassium; creat = creatinine; Hb = haemoglobin; WBC = white cell count; GCS = Glasgow Coma Score.

pH and oxygenation points required arterial blood gas analysis and many more samples were taken in the six hours before ICU admission than the other two time periods. Over 70% of blood gas results showed abnormal oxygenation (APACHE II points >0) for all time periods, although pH was rarely outside the normal range until the six hours before ICU admission.

The percentage of admissions undergoing procedures or interventions is in table 8.5. Physiotherapy was performed on about 20% of patients with no increase in treatment leading up to ICU admission. The physiotherapists usually supervise administration of CPAP. The percentage of patients on CPAP, although small, doubled over the 24 hours before ICU admission. The majority of patients were administered oxygen from at least 12 hours before admission and this percentage had risen to 75% in the

final 6 hours on the wards. At the time of the study pulse oximeters were not readily available on wards and the fact that they were used on over 30% of patients at least 12 hours before ICU admission further suggests that these patients were recognisably at risk. By the six hours before ICU admission some 60% of patients were monitored. The need for oxygen therapy, and its ultimate ineffectiveness, is illustrated by the high percentage of patients in whom a saturation of <90% was recorded in the period before ICU admission.

Table 8.5

Percentage of patients undergoing procedures/interventions before ICU admission.

procedure/intervention	12-24 hrs	6-12 hrs	0-6 hrs
ABG	13.9%	15.2%	36.7%
physiotherapy	22.8%	19.0%	20.3%
CPAP	6.3%	8.9%	12.7%
O_2	49.4%	62.0%	74.7%
SpO_2 performed	36.7%	32.9%	60.8%
SpO_2<90%	31.0%	50.0%	62.5%

ABG = arterial blood gas sample taken, physiotherapy = treated by a physiotherapist, CPAP = mask continuous positive airway pressure therapy, O_2 = oxygen administered, SpO_2 performed = patient monitored with pulse oximeter, SpO_2 <90% = percentage with lowest recorded oxygen saturation <90%.

A total of 44 patients (55.7%) died during their hospital admission. There was no statistical difference between those who did and did not receive CPR in the number of ICU or hospital deaths, or in the APACHE II score before or after ICU admission (table 8.6).

Table 8.6

APACHE II scores before and after ICU admission and ICU mortality for all admissions. Hospital mortality is for number of patients.

		no CPR	CPR
pre-ICU APACHE	Median	20	16
	Range	0-42	1-46
ICU APACHE	Median	20	23
	Range	1-50	4-41
died in ICU	Number	18	10
(% of admissions)	Percentage	(34.6%)	(37.0%)
died in hospital	Number	27	17
(% of patients)	Percentage	(52.9%)	(68.0%)

pre-ICU APACHE = APACHE II score for the 24 hours before ICU admission; ICU APACHE = APACHE II score for the 24 hours after ICU admission; died in ICU = number and percentage of ICU admissions who died during the admission; died in hospital = number and percentage of patients who died during the hospital admission.

Comparing admissions who did and did not receive CPR before ICU admission, univariate analysis was performed on the APACHE II points from the worst physiological values in the 24 hours before ICU admission. Only the p value for heart rate ($p=0.095$), respiratory rate ($p=0.052$) and pH ($p=0.087$) were less than 0.1.

Discussion.

In this study we wished to focus on patients where intervention was possible and may make a difference to outcome. We therefore excluded ICU admissions within 24 hours of surgery or within 24 hours of hospital admission. We did not collect information on patients who were not admitted to the ICU, some of whom would have had abnormal physiological values or even suffered cardiorespiratory arrest and died.

This study demonstrates that patients admitted to ICU from our wards were seriously ill. The average pre-admission APACHE II score was 19 and 34% of admissions followed CPR. A high percentage of patients had chronic health problems and in total the 76 patients studied had 93 ICU admissions with an overall hospital mortality of 58%.

Although it sometimes seems that a high proportion of ICU admissions from the ward occur at 5 p.m. on Friday, there was no clear pattern to the day of week and time of day of the ICU admissions. Despite the patients' severity of illness, routine physiological observations were not found in the notes of all patients. The data was often recorded intermittently and imprecisely and there is a need for better charting of observations. Despite these limitations a value for temperature, blood pressure, heart rate and respiratory rate was available for most patients over the 24 hours before ICU admission. Using APACHE II points as a measure of physiological derangement, of these four physiological parameters, heart rate and respiratory rate were most abnormal. There was a significant worsening of the respiratory rate over the 24 hours before ICU admission, which did not occur with heart rate. A tachycardia may be an important indicator of a patient at risk, but an increasing respiratory rate is likely to be a better sign of the imminent need for ICU admission.

Although the GCS was associated with the highest APACHE II points this is probably because a maximum of 12 can be scored. Physiological variables with low APACHE II scores, including sodium, potassium, temperature, haemoglobin, white cell count and MAP are unlikely to give an early indication of a patient at risk.

The majority of patients received oxygen. Within six hours of ICU admission an arterial blood sample was commonly taken and patients attached to a pulse oximeter. These findings suggest that medical staff recognised that many of the patients were seriously ill and were providing some additional monitoring and treatment. Despite this attention many of the patients deteriorated to the point where CPR was necessary.

Pre-admission APACHE II points were not able to identify patients requiring CPR. It is possible that many of those admitted to the ICU who did not receive CPR had severely deranged physiological values and would have required CPR if left longer on the wards.

Our hospital does not possess a High Dependency Unit (HDU) and critically ill hospital inpatients are all managed on the wards before ICU admission. One reason patients may remain too long on the wards is the perceived difficulty of obtaining an ICU admission. The problems of a multiple site hospital, unsatisfactory hand-over of patients, poor continuity of care, and inexperienced and poorly supervised trainees may all have contributed to late recognition and inadequate treatment of patients at risk.

Several previous studies have suggested that it is possible to recognise critically ill patients on the wards and that outcome could often be improved. In an investigation of hospital deaths from cerebrovascular accident, pneumonia or myocardial infarction, over one quarter of deaths were thought to have been preventable (Dubois RW and Brook RH. 1988). In two thirds of 40 British medico-legal claims in patients admitted with acute medical emergencies, clinicians either failed to recognise that the patients

were very ill or tried to manage a situation without having the necessary competence (Neale G. 1998). Neale concluded that errors probably would not have happened in half the cases had the patients been seen by experienced clinical staff shortly after admission. Schein et al (Schein RM et al. 1990) documented a clinical deterioration in 84% of patients within eight hours of an in-hospital arrest. Overall 70% of patients had deterioration of either respiratory or mental function with 25% showing a deterioration in both. Franklin and Mathew (Franklin C and Mathew J. 1994) found that a deterioration had been documented in 66% of patients who had an in-hospital cardiac arrest. Where a deterioration had been documented they found that the patient arrested either because the nurse did not inform the doctor (25%), junior doctors did not inform senior doctors (43%) or intensive care doctors did not follow usual procedures (32%). George et al (George ALJ et al. 1989) found that death after in-hospital CPR was associated with pre-arrest hypotension, renal failure and age over 64 years. A further study (Sax FL and Charlson ME. 1987) found that there was advance warning in almost all medical patients experiencing a cardiac or respiratory arrest or an abrupt haemodynamic or respiratory decompensation. The most important predictors were acute dyspnoea or deterioration of their pre-existing condition.

Our data suggest that respiratory rate, heart rate and the adequacy of oxygenation are the most important physiological indicators of a critically ill ward patient. The level of consciousness and presence of renal failure may also be important indicators. Urine volume may be a useful measure but, in our hospital, observations were not sufficiently detailed to be of value.

Interventions, such as administering oxygen, placing a patient on CPAP or taking an arterial blood gas, were carried out in many of our patients before ICU admission. Because these interventions only follow recognition that the patient is seriously ill, and depend on the policy and practice of the institution, they are less useful than physiological values as part of an objective system to identify the patient at risk.

If published guidelines for HDU and ICU admission had been followed many of the ward patients would have been admitted at an earlier stage to a critical care facility (Nasraway SA et al. 1998, NHS Executive. 1996). Franklin et al showed that opening a medical HDU in their hospital decreased mortality by 13.2% and the number of arrest on the ward by 38.8% (Franklin CM et al. 1988). Few of our ICU admissions had acute physiological deterioration or unheralded cardiac events. Many patients could have been identified and admitted to HDU/ICU earlier and it is likely that most of the cardiorespiratory arrests on the wards before ICU admission could have been prevented.

In order to provide appropriate care, critically ill hospital patients need to be identified and managed expertly in a suitable location. A medical emergency team, as described by Lee at al (Lee A et al. 1995), may be useful in the pre-arrest situation, although even earlier intervention to prevent physiological deterioration would be preferable (Goldhill DR. 1997a). Our study echoes the findings of others (Schein RM et al. 1990, Neale G. 1998, Sax FL and Charlson ME. 1987) by suggesting that medical and nursing staff are probably aware of most critically patients but, in many cases, do not provide the appropriate treatment. Abnormal values of selected physiological measurements may be useful as an objective indication that patients are at risk. If

unnecessary deaths are to be prevented such patients must be assessed early by experts in critical care medicine and the resources made available to provide these patients with appropriate treatment, which may be on the wards, in the HDU or in the ICU.

The patient at risk team: Identifying and managing seriously ill ward patients

Introduction

The physiological values described in the previous study were used as the basis of a system to identify seriously ill ward patients who might benefit from additional expert care.

We established a Patient At Risk Team (PART) (similar to the Medical Emergency team described by Lee et al (Lee A et al. 1995)) in order to allow early identification of seriously ill patients on the hospital wards and assist in their management. The PART visited patients who fulfilled certain physiological criteria as well as other patients causing concern to medical and nursing staff. The purpose was to optimise their care and improve their outcome. The PART aimed to achieve this by providing advice and support to those responsible for managing ward patients at risk of further deterioration, by facilitating early ICU admission when appropriate, and by preventing unnecessary ICU admissions thereby releasing valuable beds for use by patients in greater need.

The aims of this study were to see if the physiological criteria used to call the PART were appropriate and were useful in determining the necessity for admission to the ICU, and whether early review or intervention improved patient outcome.

Methods

This prospective study took place between the 1st June 1997 and 30th November 1997 at The Royal London Hospital, Whitechapel. An earlier audit of patients admitted to the intensive care unit (ICU) from the wards (Goldhill DR et al. 1999) suggested values of physiological variables associated with patients requiring ICU admission. Based on these findings a committee with surgical, medical, intensive care and nursing input agreed criteria for identifying high risk patients on the wards. A Patient At Risk Team (PART) was formed consisting of the ICU consultant or deputy, a senior ICU nurse and the duty medical or surgical specialist registrar as appropriate. The criteria for alerting the PART are in table 8.7. With the support of the nursing Directorate and the hospital's consultant staff this protocol was introduced onto the wards. Every ward was visited, laminated copies of table 8.7 were placed on the ward notice boards and information about the PART was circulated to nurses and doctors within the hospital.

Table 8.7

The PART protocol.

A: The senior ward nurse should contact the responsible doctor and inform them of the patient with:

any 3 or more of the following:

respiratory rate ≥ 25 breaths per minute (or < 10)
systolic blood pressure < 90 mmHg
heart rate ≥ 110 beats per minute (or < 55)
not FULLY alert and orientated
oxygen saturation < 90%
urine output < 100 ml over last 4 hours

OR the patient

not FULLY alert and orientated AND
respiratory rate ≥ 35 breaths per minute OR heart rate ≥ 140 beats per minute

Unless immediate management improves the patient the doctor should consider calling the team. Exceptionally (in emergency when responsible doctor not immediately available) the senior ward nurse may contact the team directly.

B: A doctor of registrar grade or above may call the team for any seriously ill patient causing acute concern. This will normally be done after discussion with the patient's consultant.

The consultant responsible for the patient must be informed as soon as practical that the team has been called.

The intention of the PART protocol was to alert a doctor directly responsible for a seriously ill patient. A combination of physiological abnormalities was used to prompt the ward nurses to call the doctor. If this doctor required support in caring for the patient or, in exceptional circumstances, the nurses were unable to obtain a suitable response from the doctor, the PART could be contacted directly. Doctors were also advised that they could call the PART for any seriously ill patient causing acute concern.

The early identification of a patient at risk permitted discussion on suitability for resuscitation and intensive care admission, allowed for earlier intervention to prevent physiological deterioration and aided planning of intensive care admissions and resources. After assessment some patients were transferred directly to the ICU. If the patient remained on the ward the PART would advise on patient management and decide if regular review was necessary. If no intervention was required this was also noted.

Information on each patient seen by the PART was recorded onto a form. This included the details of when the patient was seen, their age, sex and hospital admission date, and the reason for the request. A record was made of previous surgery or intensive care admission, and defined interventions and therapy. If available, a record was made of the patient's most recently recorded temperature, heart rate, systolic and diastolic blood pressures, respiratory rate, Glasgow Coma Score and oxygen saturation. If results were available from the previous 24 hours, the most recent values of serum sodium, potassium, haemoglobin, white cell count and creatinine were recorded. Values of pH, and PaO_2 and $PaCO_2$ were recorded if an arterial blood sample had been taken within six hours of the assessment. A record was made of the findings on initial assessment, of the advice given and the action taken. All patients seen by the PART were followed up to record subsequent ICU admissions, the date of hospital discharge and outcome.

Information on patients seen by the PART was examined to see if the pre-defined combination of physiological values for calling the PART were of any value. The physiological values recorded by the PART were used to assign APACHE II points

(Knaus WA et al. 1985). An APACHE II score (Knaus WA et al. 1985) was calculated by summating the points for the physiological values and adding points for age and chronic health problems. We compared the physiological values, APACHE II score, procedures and interventions for the PART assessments admitted to the ICU within 48 hours with those who stayed on the ward.

Categorical data was analysed with the Chi square test, with Yates' correction where applicable, and continuous data was evaluated with a Mann-Whitney or t-test.

Results

During the six month study period the PART was called 69 times to see 63 patients. Follow up visits are not included in this number. Six patients were each assessed twice with between seven and 74 days between assessments.

The disposition and outcome of patients assessed by the PART is in figure 8.3. Forty four percent of those assessed were admitted to ICU within 48 hours and they had a 32% mortality. Of those not admitted to ICU within 48 hours of their assessment, 29% were admitted to ICU later during their hospital stay and 26% died in hospital. Seven patients were admitted to ICU more than 48 hours following assessment, two after three days, three after five days, one after seven days and one after 33 days. Of those admitted to ICU within 48 hours, two received CPR before ICU admission. One of these patients had a cardiorespiratory arrest on the ward 30 minutes after the PART arrived. At this time the patient was in the care of the ICU team, had already been intubated and was receiving intensive resuscitation.

Following assessment and appropriate discussion, do not resuscitate orders were written for two patients. One of them was 76 years of age and had bowel cancer with liver metastases; she had been in hospital for 11 days at the time of the assessment and had undergone surgery nine days previously followed by an overnight stay in the ICU; she was discharged alive from hospital 13 days after being seen. The other patient was aged 49 years and had suffered an intracranial haemorrhage; he had been in hospital for 21 days at the time of the assessment, had not undergone surgery or been previously admitted to the ICU; he died on day he was seen.

Figure 8.3

Outcome of patients seen by the PART.

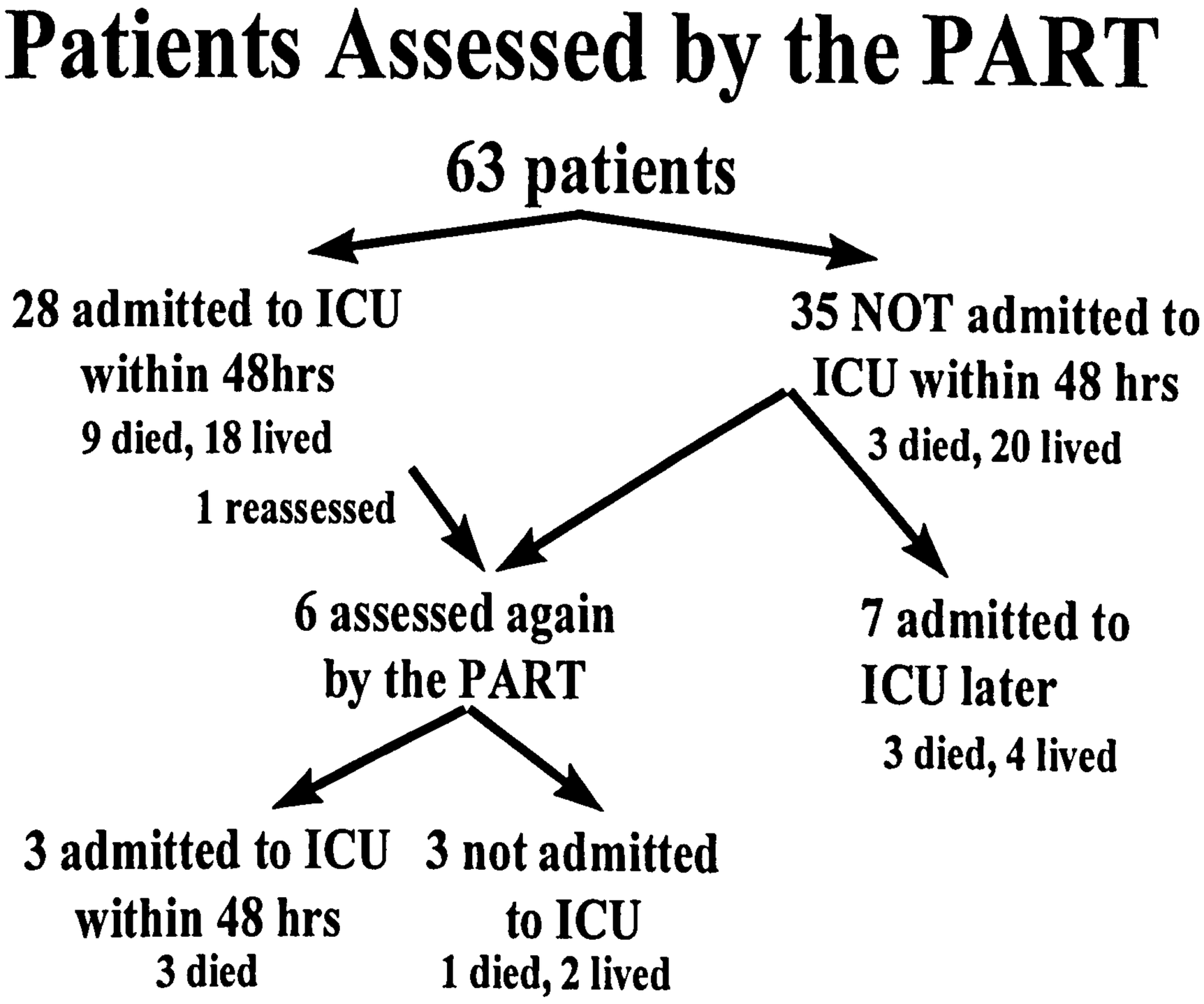


Table 8.8 contains details of the PART assessments grouped by whether they were, or were not, followed by admission to ICU within 48 hours. No statistically significant differences were found. Before assessment five patients had undergone intracranial surgery, three spinal surgery, 11 intestinal surgery, one orthopaedic surgery, two vascular surgery and six patients had undergone other operations including surgical placement of central vascular access, drainage of an abscess and wound debridement.

Table 8.8

Details of PART assessments.

	number	% male	hospital stay before assessment	average age (SD)	% previous surgery	% previous ICU
ICU	31	58.1	4 (1.5-11)	57.0 (20.7)	35.5	32.3
no ICU	38	50.0	11 (3.25-20.75)	57.3 (16.7)	44.7	36.8
all	69	53.6	8 (2-17)	57.1 (18.5)	40.6	34.8

ICU = admissions to ICU within 48 hours of assessment; no ICU = not admitted to ICU within 48 hours of assessment; all = all assessments; hospital stay before assessment = median (interquartile range) days in hospital before assessment; average age (SD) in years.

Assessments appeared to be evenly distributed throughout the weekdays with a lower percentage being performed at weekends (figure 8.4). Accurate times were available for 64 out of the 69 assessments, most of which were performed during reasonable working hours (figure 8.5).

Figure 8.4

Percentage of assessments made by the PART by day of week.

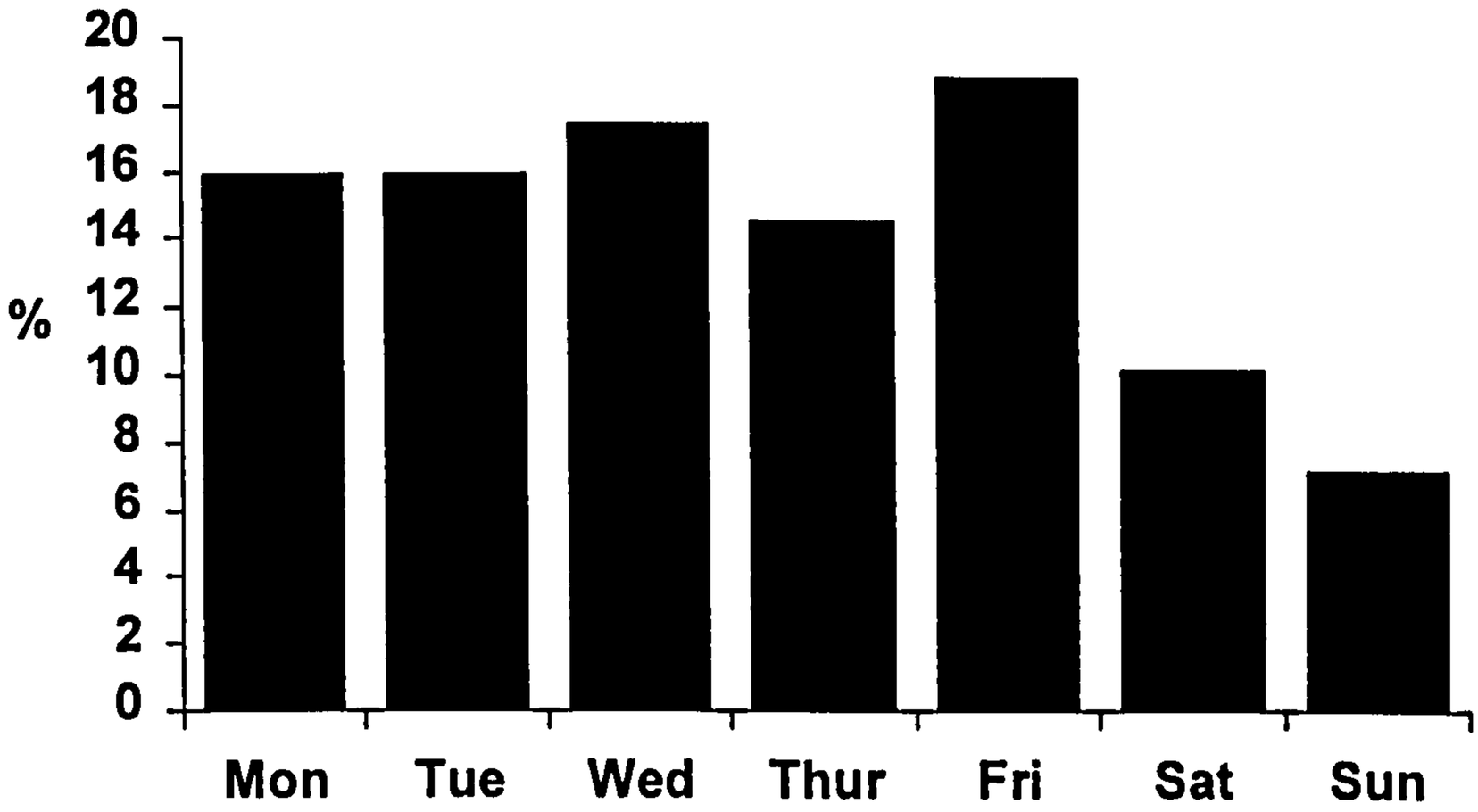
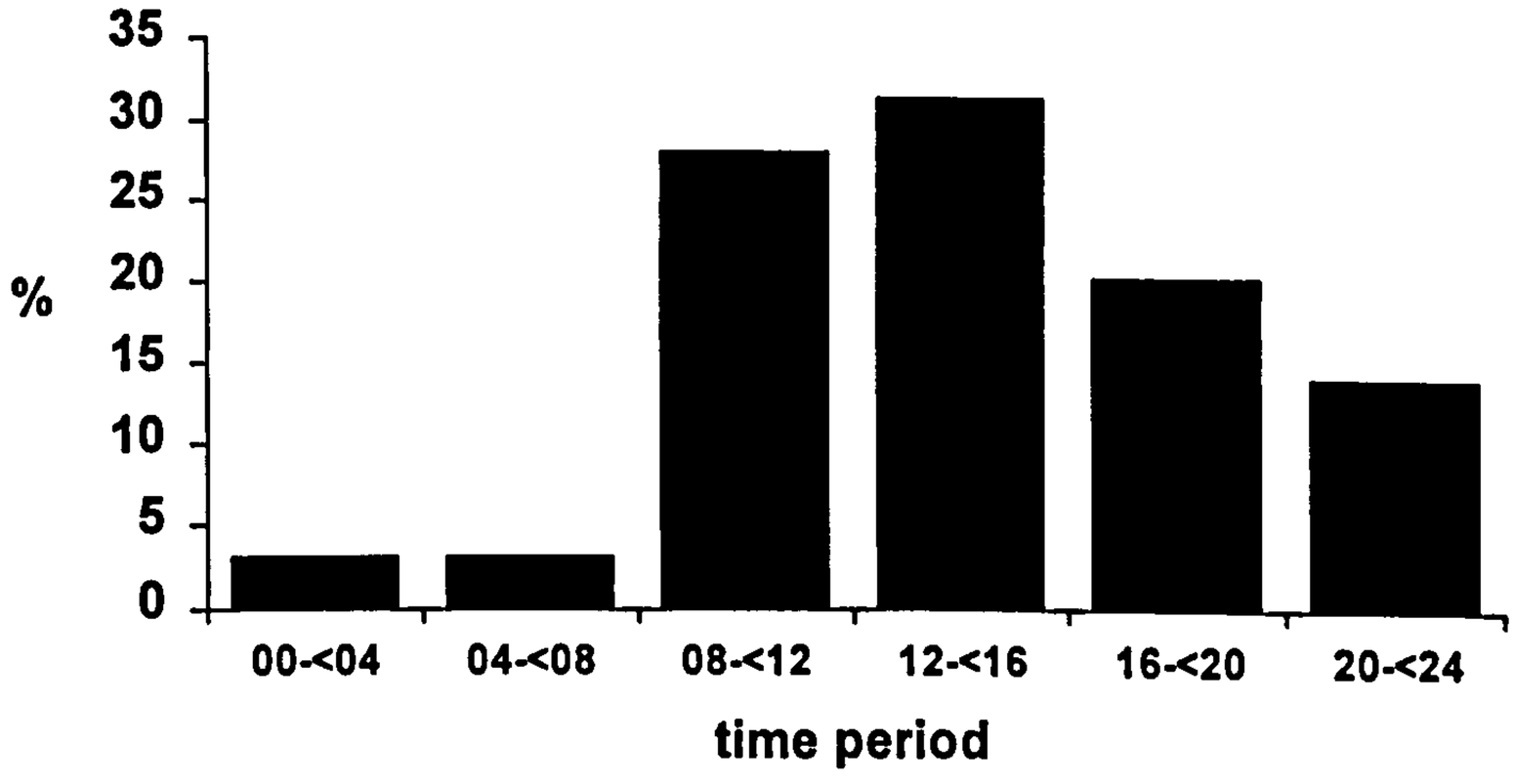


Figure 8.5

Percentage of assessments made by the PART by time period.



time period = time of assessment so that 00-<04 = between midnight and before 4 a.m., 04-<08 = between 4 a.m. and before 8 a.m. etc.

Serious chronic health problems were defined according to APACHE II (Knaus WA et al. 1985). They were common occurring in 22 (35%) of the 63 patients. The

criteria for chronic health problems are specific and describe a severe restriction on activity or risk to life.

Table 8.9 shows the percentage of admissions where a physiological value was recorded at the time of assessment.

Table 8.9

Percentage of assessments with a physiological value recorded.

	temp	HR	BP	resp	GCS	SpO_2	ABG	Na	K	Hb	WBC	creat
ICU	71	97	94	94	84	93	74	87	81	74	71	77
no ICU	82	97	97	89	89	77	61	87	84	79	76	82
all	77	97	96	91	87	81	68	87	83	77	74	80

ICU = admissions to ICU within 48 hours of assessment; no ICU = not admitted to ICU within 48 hours of assessment; all = all assessments; temp = temperature; HR = heart rate; BP = blood pressure (systolic and diastolic); resp = respiratory rate; GCS = Glasgow Coma Score; SpO_2 = oxygen saturation; ABG = arterial blood gas analysed within 6 hours of assessment; Na = sodium; K = potassium; Hb = haemoglobin; WBC = white cell count; creat = creatinine.

At least one pre-defined criteria for calling the PART was fulfilled by 96.7% of patients admitted to the ICU within 48 hours and by 82.1% of patients who remained on the wards (table 8.10). Of those admitted to ICU within 48 hours of assessment, two or more of the criteria were fulfilled by 80% and three or more by 26.7%. The equivalent figures for those who stayed on the wards were 59% and 33%. There was no significant difference in any of the individual criteria between those patients admitted to ICU within 48 hours and those not who were not. The commonest abnormality was tachypnoea, followed by a depressed level of consciousness and tachycardia.

Table 8.10

Percentage of patients fulfilling criteria for calling the PART.

	the 6 main criteria								secondary criteria:	
	1 OR		2 OR		3	4	5	6	GCS<15 and one of	
	resp>=25	resp <10	HR >=110	HR <55	SBP <90	GCS <15	SpO_2 <90	urine	resp >=35	HR >=140
ICU	58.1	3.2	38.7	0.0	22.6	51.6	19.4	19.4	9.7	3.2
no ICU	52.6	2.6	34.2	0.0	21.1	34.2	23.7	23.7	5.3	2.6
all	55.1	2.9	36.2	0.0	21.7	42.0	21.7	21.7	7.3	2.9

The criteria are those described in table 8.7. There were six main physiological criteria as well as secondary criteria. ICU = admissions to ICU within 48 hours of assessment; no ICU = not admitted to ICU within 48 hours of assessment; all = all assessments; resp = respiratory rate (breaths/min); HR = heart rate (beats/min); SBP = systolic blood pressure (mmHg); GCS = Glasgow Coma Score; SpO_2 = % oxygen saturation; urine = % with urine output less than 100 mL over 4 hours before assessment.

On assessment a decision was made either to admit the patient immediately to ICU, to review at least four hourly, to review at least daily but less frequently than every four hours, or not to keep under regular review (table 8.11). The table suggests that admission to ICU and regular review was more likely in patients with a high respiratory rate and a depressed level of consciousness. Although many of the patients had tachycardia and/or hypotension (criteria 2 and 3), they do not seem to have been a major factor in deciding on a course of action. Advice and practical help was given to the ward team responsible for the patient, primarily in the management of respiratory problems and hypovolaemia. Three patients were seen with acute surgical problems. Two were resuscitated and admitted to ICU after surgery. The third was resuscitated in ICU before the operation.

Table 8.11

Decision made at assessment by physiological criteria and APACHE II score.

			main criteria						
	number	ICU	1	2	3	4	5	6	APACHE II
admit immediately	18	100	67	33	22	50	22	22	15 (13.25-20)
review within 4 hrs	23	43	70	39	17	57	26	26	14 (10-19)
review after 4hrs	14	21	57	36	29	14	29	7	11 (7.25-16.75)
no review	12	0	33	42	25	33	8	33	10 (7-16)
do not resuscitate	2	0	0	0	0	50	0	0	6 & 18

ICU = % admitted to ICU within 48 hours of assessment; main criteria (1,2,3,4,5,6) = % fulfilling main criteria for calling team - see table 8.10; APACHE II = median (interquartile range) APACHE II score.

Physiological values were compared between those patients admitted to ICU within 48 hours of assessment and those who were not (table 8.12). Mean arterial blood pressure (MAP) was calculated as diastolic blood pressure (DBP) plus (systolic blood pressure (SBP) - DBP)/3. There was a statistically significant difference in the values of pH and white cell count. The difference in GCS narrowly failed to reach significance. The median (interquartile range) of the APACHE II scores was 14 (11-9.5) for those admitted to ICU within 48 hours of assessment and 12 (7.25-18) in those who were not.

Table 8.12

Physiological values recorded at assessment.

	temp	HR	MAP	resp	GCS	SpO_2	pH*	PaO_2	$PaCO_2$	Na	K	Hb	WBC*	creat
ICU	37.2 (0.8)	107 (18)	95 (24)	29 (10)	14 (12-15)	93.7 (3.9)	7.28 (0.2)	10.5 (3.2)	6.5 (4.6)	137 (7)	4.4 (0.7)	11.3 (2.3)	16.7 (8.0)	137 (102)
no ICU	37.3 (1.0)	106 (20)	84 (21)	28 (9)	15 (14-15)	95.0 (3.7)	7.39 (0.1)	11.3 (5.9)	5.0 (2.0)	138 (7)	4.2 (0.7)	12.2 (2.5)	11.1 (7.0)	129 (86)

Values are average (SD) apart from GCS which are median (interquartile range); ICU = admissions to ICU within 48 hours of assessment; no ICU = not admitted to ICU within 48 hours of assessment; temp = temperature (^{o}C); HR = heart rate (beats/min); MAP = mean arterial blood pressure (mmHg); resp = respiratory rate (breaths/min); GCS = Glasgow Coma Score; SpO_2 = percentage oxygen saturation; PaO_2 and $PaCO_2$ in kPa; Na = sodium (mmol/l); K = potassium (mmol/l); Hb = haemoglobin (g/dL); WBC = white cell count (10^9/L); creat = creatinine (mmol/l); * =significant difference $p< 0.05$ by t-test.

Many of the patients were already being monitored and treated more intensively than normal for the wards. Table 8.13 shows the percentage of those assessed who were monitored or receiving specific therapy.

Table 8.13

Percentage of patients with monitoring or specific therapy at assessment.

	NIBP	ECG	SpO_2	catheter	O_2	CPAP
ICU	74.2	41.9	90.3	45.2	87.1	9.7
no ICU	71.1	34.2	71.1	28.9	78.9	2.6

ICU = admissions to ICU within 48 hours of assessment; no ICU = not admitted to ICU within 48 hours of assessment; NIBP = non-invasive blood pressure measurement; SpO_2 = pulse oximetry; catheter = urinary catheter; O_2 = oxygen administered; CPAP = patient on CPAP.

Discussion

The PART was established to allow early identification of critically ill patients on the wards at The Royal London Hospital. The Royal London Hospital has a high medical and surgical emergency workload due to its inner city location, a multicultural and relatively deprived population, and to the presence of the Helicopter Emergency Medical Service (HEMS) bringing trauma patients directly to the hospital. Given this unusual case mix the results of the study may not be directly applicable to all other hospitals. However, the general principle of identifying ill patients and commencing appropriate therapy as soon as possible is relevant.

The PART was well publicised and considerable effort went into informing and educating the ward and ICU nursing and medical staff about its existence and purpose. Despite this, and because of the large number of individuals involved, the high staff turnover, and the employment of non-permanent staff, it is likely that some doctors and nurses were not familiar with the PART. Almost certainly the PART did not see all suitable patients because the doctors responsible for the patient were not aware of the PART or chose not to call it. Another difficulty was that patient assessment, and completion of the necessary paperwork, were carried out by the duty ICU resident which may have resulted in some omissions in data collection.

The PART was primarily a pre-arrest team, aimed at early intervention and prevention of in-hospital cardiac arrest. Similar teams have been established in other countries (Lee A et al. 1995) but these have generally replaced the cardiac arrest team and attended patients in all areas of the hospital. The PART ran concurrently with the arrest team and assessed ward patients only. Studies investigating in-hospital cardiac

arrest describe a very high associated mortality of 86% or greater (Bedell SE et al. 1983, Taffet GE et al. 1988). Regular revision of resuscitation guidelines and a greater emphasis placed on basic and advanced life support training amongst healthcare workers has done little to alter the outcome from cardiac arrest (Dubois RW and Brook RH. 1988). Only two patients assessed by the PART and admitted to ICU within 48 hours, suffered a cardiorespiratory arrest. One of them arrested 30 minutes after the PART arrived. At the time the patient was intubated and was being resuscitated prior to transfer to the ICU. There were 101 cardiac arrest calls to the ward during the study period and 133 in the preceding six months. There is therefore considerable potential to still improve the outcome of critically ill patients on the wards.

The criteria for calling the PART were based on the physiological values associated with ICU admission from the ward (Goldhill DR et al. 1999). They were similar to the physiological abnormalities found to precede cardiac arrest in other studies (Schein RM et al. 1990, Franklin C and Mathew J. 1994, George ALJ et al. 1989) and included tachypnoea, tachycardia, hypotension and an altered level of consciousness. The criteria identified seriously ill patients, many of whom had multiple physiological abnormalities (table 8.10) and were already being intensively monitored at the time of assessment (table 8.13). The use of monitoring and the high incidence of interventions (table 8.13) indicate that these patients were recognised by the ward staff as being critically ill before the PART was called. After a patient had been seen by the PART they were either admitted directly to the ICU or management advice was given with or without a plan for review by the PART at a later date. The ICU was often full and some patients that the PART would like to have admitted were managed

on the ward because of a lack of intensive care beds. The mortality of patients not admitted to ICU within 48 hours of assessment was high and many were admitted to the ICU later.

The commonest physiological abnormalities in the patients admitted to ICU were tachypnoea and an altered level of consciousness. It is possible that we chose to admit these patients because they would benefit from therapy available on ICU such as ventilation. Interestingly oxygen saturation was not very useful at determining ICU admission. An oxygen saturation of < 90% was more common in patients who were not admitted to ICU than those who were. A possible explanation for this is that simple respiratory problems are often managed on the ward with physiotherapy, antibiotics, oxygen and in some cases CPAP.

When the physiological values of those patients who were admitted to ICU were compared with those who were not (table 8.12), the only values which were found to be significantly different between the two groups were pH and white cell count. The difference in white cell count arose because there were four patients with leukaemia who had very low white cell counts in the group not admitted to ICU within 48 hours. The pH was determined from an arterial blood sample which was usually taken in those patients causing acute concern and thus represents a selected group of patients.

APACHE II scores were calculated for each patient from the physiological values obtained on the wards. Scores are related to the degree of physiological abnormality, selected severe chronic health disorders and the age of the patient (Knaus WA et al. 1985). The APACHE scoring system as originally described uses information

obtained during a patient's first 24 hours on ICU, not prior to admission. It can be used to predict outcome in a cohort of ICU patients but should not be used to predict individual outcome (Goldhill DR and Withington PS. 1996b, Goldhill DR and Withington PS. 1996a). Although there is a superficial relationship between the APACHE II score and the decisions made by the PART (table 8.11) the score is unlikely to be useful when making decisions with respect to individual patients.

One of the concerns expressed before the study started was that the overnight and weekend workload of the ICU resident would increase, particularly out of hours. This concern was unfounded. Only 6.2% of referrals were made between the hours of midnight and 8:00 a.m., and fewer referrals were made at the weekend than during the week. A possible explanation for the reduction in weekend referrals is that fewer doctors were on-call at weekends and consequently ward patients may have been assessed less frequently and by relatively inexperienced members of staff. Physicians and surgeons generally organise themselves into firms with a consultant responsible for trainee doctors. This system may work adequately during normal working hours when a full quota of doctors are present but it can lead to problems, particularly with continuity of care, outside of normal working hours. An on-call service usually requires cross cover between different medical teams and unless handover is thorough patients may be left in the care of doctors who have little knowledge of their past history or present complaints. Trainees in all specialities now work fewer hours and have a shorter period of training than their predecessors. This probably results in a reduction in diagnostic and 'hands on' management experience of ill patients. To compensate for this consultant staff need to have greater involvement in the planning of patient care, particularly when the patients are seriously ill. A recent study of

admissions to ICUs in two hospitals demonstrated that care before ICU admission is commonly inadequate (McQuillan P et al. 1998).

The PART functioned reasonably well during this six month pilot period. It was generally utilised appropriately by the ward staff and did not over burden the intensive care consultant, resident or senior nurse who were PART members in addition to their routine duties. It is difficult to predict whether the long term effect of the PART would be to increase or decrease the ICU workload and costs. The PART may result in fewer ICU admissions by early intervention on the wards to prevent problems. Alternatively more ICU admissions may arise by identifying patients who could benefit. If patients who previously died on the wards are admitted to ICU and still die, costs will increase without any benefit. Further investigation is necessary to answer these questions.

This study has shown that seriously ill patients, requiring intensive treatment, do exist on the hospital wards. Most of the patients were already known by the ward staff to be seriously ill. The PART probably only saw a proportion of patients who could potentially benefit from improved care. Useful decisions were made, including issuing do not resuscitate orders, and knowing about critically ill patients on the wards undoubtedly helped in planning and organising ICU admissions. Admission to a high dependency or ICU area would have been desirable for many of the patients assessed and options were limited by the lack of facilities.

Are deaths on hospital wards potentially preventable?

Introduction

Comparing ICU admissions from the operating theatres/recovery, the accident and emergency department (A&E), and the wards, the largest number and highest percentage of deaths are in patients admitted from the wards (Goldhill DR and Sumner A. 1998). Deaths of some patients who die on the ward may be preventable by early identification and ICU admission. A prospective study of all ward deaths was undertaken to quantify this problem.

Methods

The notes of all patients who died on the wards between 1st June and 30th November 1997 were examined. If a Do Not Resuscitate (DNR) order was in the notes, the time before death of the order was recorded. For patients without DNR orders information was collected on physiological values, procedures and interventions in the 24 hours before death.

Results

During the study period 317 patients died on the wards, excluding deaths in ICU, A&E, coronary care and the radiology department. A DNR order was in the notes of 262 (83%). During their admission 15 (6%) had been in ICU and 12 (5%) had received cardiopulmonary resuscitation (CPR). In 11 the date of the DNR order was uncertain. The remaining 251 patients had an average age of 74.9 years (SD 11.6, range 34-96 years) and were in hospital a median of 11 days before death (range 0-204 days). DNR orders were recorded a median of 3.2 days before death (range 0-

131 days). For 17% the DNR order was on the day of death and in 35% it was within 1 day of death.

A DNR order was not made for 55 patients (17%). However, from the diagnoses resuscitation was not always appropriate. Four (7%) had a previous ICU admission and 17 (31%) received CPR before death. Average age was 66.1 years (SD 14.7, range 21-90 years) and the median hospital stay before death was 8 days (range 0-83 days). Routine physiological values were often recorded for the 24 hours before death (table 8.14). Missing values were assumed to be normal resulting in an average APACHE II score of 13.3 (SD 6.0).

Table 8.14

Percentage of physiological values recorded and average APACHE II points in patients without a DNR order before death.

	temp	MAP	HR	resp	oxy	pH	Na	K	creat	Hb	WBC	GCS
percentage	84	76	89	64	15	16	67	65	65	60	60	7
avg points	1.0	1.5	1.8	1.2	0.9	1.9	0.2	0.3	2.2	0.7	0.8	9.3

temp = temperature; MAP = mean arterial blood pressure; HR = heart rate; resp = respiratory rate; oxy = oxygenation score; Na = sodium; K = potassium; creat = creatinine; Hb = haemoglobin; WBC = white cell count; GCS = Glasgow Coma Score; percentage = percentage for whom a value was available in the 24 hours before death; avg points = average APACHE II points in the 24 hours before death.

Discussion

Many patients who died on the wards were in hospital for some days before death. A high percentage of DNR orders were made shortly before death suggesting that active treatment was pointless at this time. However, earlier intervention may have been of benefit in some patients. Some patients without a DNR order were not appropriate for

CPR. Earlier identification, active management and ICU admission may have been of benefit in others.

Admissions from the wards to ICU; the effect of the PART.

Introduction

This following study describes the effect of the Patient At Risk Team (PART) on admissions from the wards to the ICU.

Methods

This prospective study took place between 1st June and 30th November 1997 at The Royal London Hospital. The origins, constitution and procedures for calling the PART have been described earlier.

Data was prospectively collected on all patients admitted to the ICU from the wards. This included personal details of each patient, and the date of ICU and hospital admission and discharge. Each patient's notes and the pathology computer were examined for information on physiological values, procedures and interventions for the 24 hours preceding ICU admission. Information on the ICU stay and patient outcome was obtained from the intensive care database. Further details recorded included diagnosis, history of chronic health problems, previous surgery, ICU admission or CPR during the present admission. An APACHE II score (Knaus WA et al. 1985) was calculated from the most extreme physiological values in the 24 hours

before and after ICU admission. In patients who received CPR, pre-ICU APACHE II scores were calculated using pre-resuscitation physiological values.

For all patients admitted from the wards to the ICU, we compared those patients seen by the PART within 48 hours of admission with those who were not seen. Comparisons included physiological values and the incidence of CPR in the 24 hours before ICU admission, the APACHE II scores before and after ICU admission, and ICU outcome. For analysis we used the highest values of temperature, heart rate and respiratory rate and the lowest values of mean arterial blood pressure (MAP). Similar comparisons were made in patients admitted to ICU who were not seen by the PART in the 48 hours before admission between those patients who did and those who did not receive CPR.

Statistical analysis was performed using the chi square, t-test or Mann Whitney test as appropriate.

Results

Over the six month study period 422 patients were admitted to the ICU, 119 from the accident and emergency department, 160 from the operating theatres/recovery, 99 from the hospital wards and 44 as transfers from other hospitals or critical care facilities. Data on two patients admitted from the wards, one within 48 hours of a PART assessment, were not recorded at ICU admission and their notes were subsequently misplaced. They are not included in the analysis. During this period the PART made 69 separate assessments on 63 patients. Following the assessments, 31 patients were admitted to ICU within 48 hours. Two of these patients had surgery

after the assessment and before ICU admission. Information is therefore presented on 28 patients admitted from the wards to the ICU having been assessed by the PART within 48 hours of admission and 69 patients who were not assessed by the PART before admission (table 8.15).

Table 8.15

Details of patients admitted from the ward to the ICU.

	seen by PART	not seen by PART	
number of admissions	28	69	
number (%) CPR before ICU	1 (3.6)	21 (30.4)	p<0.005
number (%) died in ICU	7 (25.0)	31 (44.9)	NS p=0.07
age	55 (21.1)	53 (17.8)	
% male	54	54	
days in hospital	5.5 (1-17.5)	6 (1-16)	
ICU stay	5.5 (1-9.25)	2 (1-6)	
ICU stay survivors	6 (2-9)	2 (1.25-5.75)	
% previous ICU	29	17	
% previous surgery	39	49	
pre-APACHE	14 (11-20)	16 (9-20)	
ICU-APACHE	20.5 (11-27)	21 (13-30)	

Seen by PART = seen by the PART within 48 hours of ICU admission; CPR = cardiopulmonary resuscitation; age = average age in years (SD); days in hospital = median (interquartile range) of days in hospital before ICU admission; ICU stay = median (interquartile range) days in ICU; ICU stay survivors = median (interquartile range) days for those who survived to leave ICU; pre-APACHE = median APACHE II score (interquartile range) from values from the 24 hours before ICU admission; ICU APACHE = median APACHE II score (interquartile range) from values from the 24 hours after ICU admission.

One patient had a cardiorespiratory arrest on the ward 30 minutes after the PART arrived. At this time the patient was in the care of the ICU team, had already been intubated and was receiving intensive resuscitation. We have not included this patient in the numbers of those who arrested before intensive care began. There was a highly significant difference in the number of patients who received CPR before ICU

admission. Although there was a difference in percentage ICU mortality this did not reach statistical significance. The data demonstrate that the majority of the patients were in hospital for some days before their ICU admission. Many had previously undergone surgery and/or a previous ICU admission.

The differences between those who were or were not seen by the PART may reflect the fact that advanced respiratory care is only available in the ICU as well as the practice of individual medical and surgical firms (table 8.16). In this way the PART may have been called more frequently to patients with severe respiratory or airway problems, and critically ill neurosurgical and other patients may be routinely looked after on the wards and only come to the attention of the ICU when admission is necessary.

Table 8.16

Reasons for ICU admission.

	number (%)	
main reason for ICU admission from the wards	**seen by PART**	**not seen by PART**
Respiratory aspiration, asthma, COAD, chest infection, postoperative respiratory support, post respiratory arrest.	16 (57)	23 (33)
Cardiovascular CCF, IHD, hypovolaemic shock, abnormal rhythm, post cardiac arrest, cardiogenic shock, sepsis.	6 (21)	19 (28)
Neurological muscle weakness, fits, intracranial haemorrhage, meningitis, intracranial neoplasm, spinal cord injury.	2 (7)	16 (23)
Gastrointestinal pancreatitis, hepatic failure, GI haemorrhage, perforation/obstruction.	4 (14)	9 (13)
Metabolic diabetic ketoacidosis.	0	2 (3)

Seen by PART = seen by the PART within 48 hours of ICU admission; COAD = chronic obstructive airways disease; CCF = congestive cardiac failure; IHD = ischaemic heart disease; GI = gastrointestinal.

The percentage of patients for whom a physiological value was available for the 24 hours before ICU varied widely (table 8.17). For many of the physiological parameters the average worst values were well outside the normal range. The pH, PaO_2 and $PaCO_2$ required analysis of an arterial blood sample. The GCS was most likely to be recorded in patients with a depressed level of consciousness. Several patients not seen by the PART had very high levels of PaO_2 which probably reflected the inspired oxygen concentration and is unlikely to be clinically relevant.

Table 8.17

Physiological values recorded in the 24 hours before ICU admission.

		seen by PART	not seen by PART	
	% available	average SD	average SD	
high temp	76	37.6 (1.1)	37.6 (1.1)	
low MAP	76	73 (15.6)	72 (26.7)	
high HR	85	124 (16.1)	117 (24.1)	
high resps	76	35 (9.5)	31 (11.2)	
pH	62	7.31 (0.2)	7.28 (0.2)	
Na	86	138 (6.4)	137 (6.6)	
K	82	4.3 (0.7)	4.1 (0.9)	
creatinine	84	145 (124)	148 (122)	
Hb	85	10.9 (2.6)	11.1 (2.4)	
WBC	85	15.6 (8.2)	12.1 (7.3)	
PaO2	65	9.0 (2.3)	19.3 (17.6)	p=0.01
PaCO2	65	6.5 (3.6)	5.9 (3.2)	
		median range	median range	
low GCS	19	11.5 (7.25-12)	3 (3-7.5)	

seen by PART = admitted to ICU within 48 hours of the PART assessment; SD = standard deviation; % available = % of ICU admissions for whom a value for the physiological variable was found in the notes or on the pathology computer; temp = temperature ^{O}C; MAP = mean arterial blood pressure (mmHg), HR = heart rate (beats per minute), resps = respiratory rate (breaths per minute); Na = sodium (mmol/L); K = potassium (mmol/L); Hb = haemoglobin (g/dL); WBC = white cell count $10^9/L$, PaO_2 and $PaCO_2$ in KPa; GCS = Glasgow Coma Score, median and interquartile range.

Table 8.18 suggests that there may be a difference in the pattern of physiological abnormalities in ICU admissions between those seen and those not seen by the PART. A higher percentage of those seen by the PART had tachypnoea, tachycardia and desaturation and were more likely to fulfil two or more of the six main criteria. Only 15% of patients seen by the PART and admitted to ICU within 48 hours fulfilled one or none of the criteria compared with 47% of the other ICU admissions.

Table 8.18

The percentage of ICU admissions from the ward fulfilling the six main PART criteria and the number and percentage fulfilling a given number of these criteria.

	The 6 main PART criteria										
	resp >=25	SBP <90	HR >=110	GCS <15	SpO2 <90%	urine	0 criteria	1 criteria	2 criteria	3 criteria	>3 criteria
seen by PART	68	29	71	21	50	21	3 (11)	1 (4)	7 (25)	11 (39)	6 (21)
not seen by PART	42	26	56	28	26	12	13 (19)	19 (28)	13 (19)	13 (19)	11 (16)

seen by PART = admitted to ICU within 48 hours of the PART assessment; resp = respiratory rate; SBP = systolic blood pressure; HR = heart rate; GCS = Glasgow Coma Score; SpO_2 = oxygen saturation; urine = urine output < 100 mL over 4 previous hours; 0 criteria = number (percentage) of admissions fulfilling 0 of the six main criteria for calling the PART etc.

A limited number of pulse oximeters were available for use on the wards. Despite this oxygen saturation (SpO_2) values were recorded during the 24 hours before ICU admission on 75% of admissions seen by the PART, and 54% of the other ICU admissions. Oxygen administered with continuous positive airway pressure (CPAP) is very rarely used on the wards. The number of patients on CPAP, particularly those seen by the PART within 48 hours of ICU admission, suggests that many were recognised to have severe respiratory dysfunction (table 8.19).

Table 8.19

The percentage of ICU admissions from the ward being monitored or receiving oxygen on the wards in the 24 hours before ICU admission.

	NIBP	ECG	SpO_2	catheter	O_2	CPAP	CVP
seen by PART	46	14	88 (86-93)	32	79	18	25
not seen by PART	42	9	90 (86-94)	33	67	6	20

seen by PART = admitted to ICU within 48 hours of the PART assessment; NIBP = non-invasive blood pressure measurement; ECG = continuous electrocardiogram monitoring; SpO_2 = median lowest percentage oxygen saturation (interquartile range) recorded during the 24 hours before ICU admission; catheter = urinary catheter in place; O_2 = oxygen administered; CPAP = continuous positive airway pressure administered; CVP = central venous access in place.

In table 8.20 admissions not seen by the PART have been divided by whether they did or did not receive CPR in the 24 hours before ICU.

Table 8.20

Details of patients not seen by the PART and admitted from the ward to the ICU.

	not seen by PART		
	no CPR	CPR pre-ICU	
number of admissions	48	21	
number (%) died in ICU	19 (39.6)	12 (57.1)	
age	49 (18.8)	61 (12.4)	p=0.01
days in hospital	6 (1.75-15.25)	3 (1-26)	
ICU stay	2 (1-7)	2 (1-4)	
ICU stay survivors	2 (1-9)	2 (2-4)	
pre-APACHE	16.5 (11-20)	13 (7-21)	
ICU-APACHE	19.5(12.75-26)	26 (17-32)	p=0.07

CPR = cardiopulmonary resuscitation; age = average age in years (SD); days in hospital = median (interquartile range) of days in hospital before ICU admission; ICU stay = median (interquartile range) days in ICU; ICU stay survivors = median (interquartile range) days for those who survived to leave ICU; pre-APACHE = median APACHE II score (interquartile range) from values from the 24 hours before ICU admission; ICU APACHE = median APACHE II score (interquartile range) from values from the 24 hours after ICU admission.

Discussion

The introduction of the PART was prompted by the high percentage mortality in patients admitted to the ICU from ward areas (Goldhill DR and Sumner A. 1998). As these patients are already within the hospital, and therefore accessible, it is possible to introduce changes in management to provide early intervention with the aim of reducing mortality. The PART protocol was a simple way to try to identify critically ill patients on the wards. Similar teams have been established in other countries (Lee A et al. 1995). The physiological criteria, based on ICU admissions from the wards (Goldhill DR et al. 1999), were similar to the physiological abnormalities found to

precede cardiac arrest in other studies (Franklin C and Mathew J. 1994, George ALJ et al. 1989). These included an abnormal respiratory rate, abnormal pulse rate, hypotension and an altered level of consciousness. However the physiological criteria used to notify the PART are unlikely to work for all patients as 40% of patients seen by the PART within 48 hours of ICU admission fulfilled fewer than three of the six main criteria as did 64% of those not seen by the PART. Although most of the patients fulfilled at least one criteria, 17% of ICU admissions from the ward did not fulfil any of the criteria. Many of these patients must have been recognised as being seriously ill with a high percentage being monitored and receiving oxygen on the ward before ICU admission.

The early identification of the patient permitted discussion on suitability for resuscitation and intensive care admission, allowed for earlier intervention to prevent physiological deterioration and aided planning of intensive care admissions and resources. After assessment some patients were transferred directly to the ICU. If the patient remained on the ward the PART advised on patient management and decided if regular review was necessary.

Of the 97 patients admitted to ICU from the ward, 28 were seen by the PART within the preceding 48 hours. The incidence of CPR amongst this group was strikingly and significantly lower than among those patients not assessed by the PART on the ward before ICU admission. Studies in patients who suffer an in-hospital cardiac arrest consistently demonstrate a very high mortality rate (Bedell SE et al. 1983, Taffet GE et al. 1988), and there is likely to be considerable benefit from preventing the need for CPR.

Despite the availability of the PART the majority of patients were not assessed before admission to the ICU and a high percentage of these patients received CPR before admission. The PART was widely publicised but it is possible that some doctors and nurses were unaware of its existence. There was no compulsion to call the PART and the decision to do so was the responsibility of the doctor caring for the patient. The data does not suggest that there was a marked difference in physiological values between the two groups. It does demonstrate that many of the patients not seen by the PART had physiological abnormalities and were being actively monitored and treated in the 24 hours before ICU admission.

The Royal London Hospital and its ICU are not typical and have a higher than usual number of emergency, trauma and seriously ill patients. There are no high dependency beds within the hospital, which may restrict access to critical care facilities. The workload and impact of the PART may therefore not be directly applicable to some other hospitals. The PART appeared to be successful in preventing the need for CPR and may help decrease the mortality of critically ill patients on the wards. A recent study of pre-ICU care showed that management of critically ill patients was often sub-optimal (McQuillan P et al. 1998). Much more could be done to prevent and treat physiological abnormalities in these patients and to prevent the need for cardiopulmonary resuscitation. Early identification of critically ill patients is essential combined with timely, appropriate treatment on the wards or in high dependency or intensive care facilities.

9. The Future

Strengths of ICARUS

Despite the fact that there have been many changes in intensive care audit since ICARUS was introduced it remains an effective and simple method for collecting intensive care data.

The information collected fulfils current recommendations. In particular APACHE II remains, for the present, the preferred method in the United Kingdom for comparing the performance of ICUs. The design of the form has stood the test of time and has been used without alteration for over 7 years. The layout of the form makes clear the scoring structure of the APACHE II system. In addition definitions are given for abnormalities in chronic health that score points in the APACHE II system. This should help explain elements of the APACHE II system to those involved in form completion. The colour coding means that it is easy to assign responsibility for completing certain area.

The method of collecting data using an OMR form has proved to be effective and reliable. The system is relatively inexpensive requiring little in the way of hardware, software and personnel. The form stays by the patient's bedside and is less likely than other methods to become mislaid or lost. The paper record provides a method of retrieving information in the event of a computer failure. The information does not take long to gather and is reliably entered into the computer. As the system is used within a region it has become familiar to trainee doctors on rotation and this has

decreased the necessity for training and probably enhanced the reliability and acceptability of the system.

The system of collecting data on a regional basis has provided the basis for regular regional audit meetings. The information in ICARUS has usually suggested topics for discussion or been a resource for local information on the topics discussed. The system has encouraged regional co-operation and enabled intensivists in the region to get to know one another better. The information in ICARUS has been used to support individual intensive care units in their bids for resources.

The information in ICARUS has been used to contribute towards an understanding of the limitations of methods for severity scoring and case mix adjustment. An analysis of ICARUS data has helped to identify priorities for intensive care and has led to alterations in intensive care practice at The Royal London Hospital and has supported ideas for ways in which care for critically ill patients can be improved.

Weaknesses

The typeset pre-printed form only allows for a limited data set to be entered. It is also inflexible so that alterations and additions are difficult to make. The OMR form is unsuitable for certain information, although this was partly addressed by entering some of the data through a keyboard. The limitations of the form requires that much of the physiological APACHE II data be added by indicating a range. It would be better if the actual values could be entered. This allows the computer to pick the

worst score from a high and low value and permits later analysis based upon the actual data values.

The OMR forms are not entered into the computer until, at the earliest, after the patient's discharge from ICU. Forms from ICUs throughout the region are often not entered until several months after the patient has been discharged. At this time it is very difficult to correct any inaccurate or missing data as patients' charts may not be available and the doctors involved may have moved on or have little recall of the details of the case. It is also not possible to use the data on the OMR form to contribute to a discharge summary.

Because the data is gathered and analysed centrally contributing ICU may be less committed to the process and feel less ownership of the data. Without immediate access to the data, reports for individual ICUs are more difficult to organise and less use is likely to be made of the data in local ICUs.

The future

Over the years that ICARUS has been in use there have been enormous developments in computer hardware and software. The price of computers has fallen dramatically and it is a rare ICU that does not have access to one. The software to enter, analyse and present data has improved beyond measure. Developments, allowing much of the required ICU data to be sampled directly from monitors or other computers, are far advanced.

In parallel most intensivists support the necessity of recording ICU audit data. In the United Kingdom this has been reflected in Government funding to set up ICNARC and the support given to it by many individuals and ICUs.

There has been much interest in the development of appropriate audit tools, although it is my belief that predicting outcome at admission for groups of intensive care patients is unlikely to be significantly more accurate than at present. There appears to be little prospect of accurately and objectively predicting outcome for individuals with the crude physiological values used at present. Severity adjustment systems do allow us to describe ICU patients and have contributed to a much better understanding of the patients and the process of care received in the ICU.

Above all there has been an increasing professionalism in the process of intensive care audit. Thus national and international organisations are discussing the intensive care information to be collected. Hardware and software for intensive care audit are now commercially produced and analysis and presentation are undertaken by trained statisticians and programmers.

For these reasons the ICARUS system is reaching the end of its useful life. The process of intensive care audit will continue but in the future it should be under the auspices of national organisations such as ICNARC. The days of the OMR form are probably numbered, although they may still be useful as a means of entering part of the data. I hope that the ICARUS information will continue as part of a continuous and growing national intensive care database.

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NORTH EAST THAMES

ICU AUDIT SYSTEM

READ NOTES ON FORM FILLING!

Use only a soft pencil, don't press hard, use an eraser for errors

UNIT CODE

1st/2nd Unit

01/02 Basildon
03/04 Broomfield
05/06 Chase Farm
07/08 Colchester
09/10 Homerton
11/12 King George's
13/14 Middlesex
15/16 Newham
17/18 North Middlesex
19/20 Oldchurch
21/22 Orsett
23/24 PAH Harlow
25/26 Royal Free
27/28 Royal London
29/30 Southend
31/32 St. Andrew's, Billericay
33/34 St. Andrew's, Bow
35/36 St. Bartholomew's
37/38 UCH
39/40 Whipps Cross
41/42 Whittington
43/44
45/46

PATIENT NUMBER

Sequentially from 0001
restarting 1st Jan each year

HASC

53 Burns Unit
54 Cardiac Surgery
07 Cardiology
42 Cold Orthopaedics
05 Dermatology
14 ENT
60 Endocrinology
62 Gastroenteroloy
01 General Medicine
13 General Surgery
11 Geriatrics
25 Gynaecology
63 Haematology
03 Infectious Diseases
67 Medical Oncology
68 Nephrology
06 Neurology
24 Neurosurgery
26 Obstetrics
17 Opthalmology
22 Oral Surgery
02 Paediatrics
70 Paediatric Surgery
20 Plastic Surgery
04 Pulmonary Medicine
18 Radiotherapy
10 Rheumatology
28 Special Care Babies
75 Spinal Injuries
21 Thoracic Surgery
43 Traumatic Orthopaedics
40 Transplant Surgery
77 Tropical Medicine
19 Urology
80 Vascular Surgery

ACTIVE CANCER:

Within 6 months of ICU admission

PROBABLE INFECTION:

Gross purulence; antibiotics being given to treat probable infection (NOT prophylactic antibiotics); extensive soft tissue injury/open wound following trauma; probable infection investigated with cultures/Gram stain etc.

CPR:

Cardiac massage/defibrillation within 24 hrs of ICU admission

APACHE II SCORING

ON ADMISSION: use worst result from 1 hr before to 2 hrs after ICU admission
AT 24 hrs: use worst within 24 hrs INCLUDING admission data

CHRONIC HEALTH SCORE

LIVER

Biopsy proven cirrhosis and documented portal hypertension; or episodes of past upper GI bleeding attributed to portal hypertension; or prior episodes of hepatic failure/coma/encephalopathy

CARDIOVASCULAR

NYHA class IV; cardiac disease resulting in inability to carry on ANY physical activity without discomfort: may be present even at rest

RESPIRATORY

Chronic restrictive, obstructive or vascular disease resulting in severe exercise restriction; or chronic hypoxia, hypercapnoea, 2° polycythaemia, pulmonary hypertension (> 40mm Hg); or ventilator dependency

RENAL

Receiving chronic dialysis

IMMUNO-COMPROMISED

Therapy: current high-dose steroids (> 15 mg/kg methylprednisolone or equivalent daily, for ⩾ 5 days); or active chemo- or radiotherapy within 1 year; or chemo- or radiotherapy at anytime for any lymphoma
Disease: documented immunohumoral or cellular immune deficiency state; or an advanced disease suppressing resistance to infection (e.g. leukaemia, lymphoma, AIDS, documented diffuse metastatic cancer

ACUTE RENAL FAILURE

Creatinine > 125 uMol/l first manifest within 48 hrs of admission
AND oliguria (urine < 135 ml/8hr)

GLASGOW COMA SCORE

Use last known values, assume normal unless evidence otherwise

APACHE II

Respiratory

01 Aspiration/Poisoning/Toxic
02 Asthma/Allergy
03 COPD/COAD
04 Pulmonary Infection
05 Post Surgical Insufficiency
06 Pulmonary Embolus
07 Pulmonary Neoplasm
08 Pulmonary Oedema (non cardiogenic)
09 Post Respiratory Arrest
10 Respiratory Observation

Cardiovascular

11 Aortic (including thoracic) Aneurysm
12 Congestive Cardiac Failure
13 Coronary Artery Disease/M.I.
14 Heart Valve Disease
15 Hypertension
16 Pericardial Disease
17 Peripheral Vascular Disease
18 Rhythm Disturbance
19 Shock - Anaphylactic
20 Shock - Cardiogenic
21 Shock - Hypovolaemic
22 Bleeding but not Shock
23 Sepsis
24 Burns
25 Multiple Trauma
26 Simple Trauma

Neurologic

27 Trauma Head Injury alone
28 Intracranial Bleeding
29 CNS Infection
30 Neoplasm
31 Neuromuscular Failure
32 Seizures/Fits
33 Spinal Operation

Gastrointestinal

34 Bleeding
35 Hepatic/Pancreatic Disease
36 G.I. Neoplasm
37 Perforation/Obstruction

Renal/Urological

38 Neoplasm
39 Transplant

Metabolic

40 Overdose
41 Diabetic Ketoacidosis

If none of above codes are appropriate for MAIN diagnosis use below:

50 Respiratory
51 Cardiovascular
52 Neurological
53 Gastrointestinal (inc. Oesophagus/Liver/Pancreas)
54 Renal (inc. Genito-Urinary Tract)
55 Metabolic
56 Haematologic

RESEARCH

1	6
2	7
3	8
4	9
5	10

NETRHA ICU AUDIT

SURNAME

FORENAME

HOSPITAL NUMBER

HOSPITAL

ADMITTING CONSULTANT

PATIENT'S POST CODE

PLEASE MARK ALL FIELDS BY FILLING IN THE APPROPRIATE BOX LIKE THIS — USE A SOFT PENCIL

ID CODE — HOSP CODE (0 1 2 3 4 5 6 7 8 9) — PATIENT CODE (0 1 2 3 4 5 6 7 8 9)

THIS HOSPITAL ADMISSION DATE — DAY (10 20 30) — MONTH (1 2 3 4 5 6 7 8 9) — YR. (91 92 93 94 95 96 97 98 99)

THIS ICU ADMISSION DATE — DAY (10 20 30) — MONTH (1 2 3 4 5 6 7 8 9) — YR. (91 92 93 94 95 96 97 98 99)

TIME 24HR CLOCK — HOURS (0 1 2)

DATE OF BIRTH — DAY (10 20 30) — MONTH (1 2 3 4 5 6 7 8 9) — YR. (10 20 30 40 50 60 70 80 90)

SEX

- Male
- Female

RACE

- Caucasian
- Asian
- Negroid
- Mongoloid
- Hispanic
- Polynesian
- Other

HASC — CODE (0 1 2 3 4 5 6 7 8 9)

ADMITTED TO ICU FROM:

- Other Hospital
- Theatre/recovery
- A and E
- Ward
- HDU
- Other ITU

RECENT PAST HISTORY

	Y	N
Previous ICU admission		
Probable infection		
Active cancer		
CPR ⩽ 24 hrs ago		
Emergency operation		
Unexpected complications		

PREDICTED OUTCOME

- Expected to live
- Likely to live
- Even chance
- Likely to die
- Expected to die

APACHE II : CHRONIC

	Y	N
LIVER		
CARDIOVASCULAR		
RESPIRATORY		
RENAL		
IMMUNO-COMPROMISED		

APACHE: ON ADMISSION *(On ICU or shortly before admission)*

	+4	+3	+2	+1	0	+1	+2	+3	+4
TEMP	⩾ 41°	39-40.9°		38.5-38.9°	36-38.4°	34-35.9°	32-33.9°	30-31.9°	⩽ 29.9°
MAP	⩾ 160	130-159	110-129		70-109		50-69		⩽ 49
HR	⩾ 180	140-179	110-139		70-109		55-69	40-54	⩽ 39
RESP	⩾ 50	35-49		25-34	12-24	10-11	6-9		⩽ 5
pH	⩾ 7.7	7.6-7.69		7.5-7.59	7.33-7.49		7.25-7.32	7.15-7.24	⩽ 7.14
Na	⩾ 180	160-179	155-159	150-154	130-149		120-129	111-119	⩽ 110
K	⩾ 7	6-6.9		5.5-5.9	3.5-5.4	3-3.4	2.5-2.9		⩽ 2.4
CREAT	⩾ 302	169-301	125-168		54-124		⩽ 53		
Hb	⩾ 20		16.7-19.9	15.4-16.6	10.0-15.3		6.8-9.9		⩽ 6.7
WBC	⩾ 40		20-39.9	15-19.9	3-14.9		1.0-2.9		< 1

FIO₂ (0 1 2 3 4 5 6 7 8 9)

PaO₂ (0 1 2 3 4 5 6 7 8 9)

PaCO₂ (0 1 2 3 4 5 6 7 8 9)

TRAUMA Y N

- Blunt
- Penetrating

RTS ON HOSPITAL ADMISSION (0 1 2 3 4 5 6 7 8 9)

ISS AT HOSPITAL DISCHARGE (0 1 2 3 4 5 6 7 8 9)

RESEARCH	APACHE II CODES
0	0 0
1	1 1
2	2 2
3	3 3
4	4 4
5	5 5
6	6 6
7	7 7
8	8 8
9	9 9

	Y	N
Acute renal failure		
Ventilated		
Sedated		
Paralysed		
Intubated		

GLASGOW COMA

EYES OPEN	VERBAL	MOTOR
Never	None	None
Pain	Garbled	Extension
Speech	Inappropriate	Flexion
Spont	Confused	Withdraw
	Orientated	Localise
		Obeys

Please write a brief admission diagnosis:

RECORD OF THERAPY

NURSING DEPENDENCY	RESPIRATORY SUPPORT	MONITORING	RENAL SUPPORT	CARDIOVASCULAR	NUTRITION	ANALGESIA	
Low (0.5)	Oro-tracheal tube	CVP	Haemofiltration	Vasoactive infusion 1	Enteral (tube or oral)	Systemic analgesia	ADMIS.
Medium (1.0)	Naso-tracheal tube	Arterial cannula	Haemodialysis	Vasoactive infusion 2	Parenteral	Regional analgesia	1
High (1.5)	Tracheostomy	PA catheter	Peritoneal dialysis	Vasoactive infusion 3	None	Sedation	2
Very High (⩾ 2.0)	Spontaneous breathing	Cardiac output		Pacing		Muscle relaxation	3
	Mechanical ventilation	EEG		IABP/Mechanical assist			4
		Intracranial pressure					5
							6
							7 DAY
							8
							9
							10
							11
							12
							13
							14
							15 to DISCH.

APACHE : 24 HOURS - WORST SCORE

	+4	+3	+2	+1	0	+1	+2	+3	+4	FIO₂	PaO₂	PaCO₂
TEMP	⩾ 41°	39-40.9°		38.5-38.9°	36-38.4°	34-35.9°	32-33.9°	30-31.9°	⩽ 29.9°	0	0	0
MAP	⩾ 160	130-159	110-129		70-109		50-69		⩽ 49	1	1	1
HR	⩾ 180	140-179	110-139		70-109		55-69	40-54	⩽ 39	2	2	2
RESP	⩾ 50	35-49		25-34	12-24	10-11	6-9		⩽ 5	3	3	3
pH	⩾ 7.7	7.6-7.69		7.5-7.59	7.33-7.49		7.25-7.32	7.15-7.24	⩽ 7.14	4	4	4
Na	⩾ 180	160-179	155-159	150-154	130-149		120-129	111-119	⩽ 110	5	5	5
K	⩾ 7	6-6.9		5.5-5.9	3.5-5.4	3-3.4	2.5-2.9		⩽ 2.4	6	6	6
CREAT	⩾ 302	169-301	125-168		54-124		⩽ 53			7	7	7
Hb	⩾ 20		16.7-19.9	15.4-16.6	10.0-15.3		6.8-9.9		⩽ 6.7	8	8	8
WBC	⩾ 40		20-39.9	15-19.9	3-14.9		1.0-2.9		< 1	9	9	9

ICU DISCHARGE

DAY	MONTH	YR.	HOURS
			0 0
10 1	10 1	91	10 1
20 2		2 92	20 2
30 3		3 93	3
4		4 94	4
5		5 95	5
6		6 96	6
7		7 97	7
8		8 98	8
9		9 99	9

HOSP. DISCHARGE OR DEATH

DAY	MONTH	YR.
10 1	10 1	1
20 2		2 2
30 3		3 3
4		4 4
5		5 5
6		6 6
7		7 7
8		8 8
9		9 9

STATUS ON ICU DISCHARGE

Alive ☐ Dead ☐

If alive sent to

Ward ☐
HDU ☐
ICU ☐
Home ☐

If Dead-

Organ donor Y ☐ N ☐
Heart ☐
Liver ☐
Kidney ☐
Cornea ☐
Other ☐

STATUS ON HOSP. DISCHARGE

Alive ☐
Dead ☐

Acute renal failure	Y ☐	N ☐
Ventilated	Y ☐	N ☐
Sedated	Y ☐	N ☐
Paralysed	Y ☐	N ☐
Intubated	Y ☐	N ☐

GLASGOW COMA

EYES OPEN	VERBAL	MOTOR
Never ☐	None ☐	None ☐
Pain ☐	Garbled ☐	Extension ☐
Speech ☐	Inappropriate ☐	Flexion ☐
Spont ☐	Confused ☐	Withdraw ☐
	Orientated ☐	Localise ☐
		Obeys ☐

Discharge Summary

NORTH THAMES
INTENSIVE CARE AUDIT
Form Completion Manual

V 1.3

Answer all questions
USE A SOFT (2B) PENCIL
Use an eraser for mistakes.
Every admission to your ICU requires completion of a database form. There are NO exclusions from this.
A patient who is admitted more than once needs a separate form for each admission.
A patient transferred from another ICU requires a new form on admission to your ICU.

Please refer to notes attached to the form for codes and additional information.

DATA TO BE COMPLETED AT TIME OF ADMISSION

SURNAME
Patient's last or family name.

FORENAME
Patient's christian or given name.

HOSPITAL NUMBER
Your hospital's patient reference number. Do not use emergency numbers.

HOSPITAL
The name of your hospital or unit.

REFERRING CONSULTANT
The name of the consultant (e.g. surgeon, physician) under whom the patient has been admitted to the ICU. SURNAME THEN INITIALS

PATIENT'S POST CODE
Enter the post code for the patient's permanent residence, if living abroad then country of residence. If no fixed abode write NO FIXED ABODE.

ID CODE
UNIT Each hospital has two codes available for use in different clinical areas (e.g. ICU or HDU). Please use one code for each clinical area.

PATIENT

Number sequentially starting from 0001 for the first admission on the 1st January each year. ALL ADMISSIONS require completion of a database form. Thus if a patient is admitted several times to the ICU a new form is required for each admission. In the database the year number is prefixed to the patient number to provide a unique patient code.

THIS HOSPITAL ADMISSION DATE

The date of this admission to your hospital.

THIS ICU ADMISSION

DATE/TIME (day/month/year) of this admission to your ICU.
Time to nearest hour (24 hour clock).

DATE OF BIRTH day/month/year

SEX Genetic

RACE (racial origin, not place of birth or domicile)

Caucasian	European
Asian	Indian subcontinent
Negroid	African or West Indian
Mongoloid	Chinese, Japanese
Hispanic	Portuguese, Spanish, Latin America
Polynesian	Pacific Islands etc.
Other	

HASC Hospital Activity Speciality Code (see notes attached to form for codes)

One code per admission. Major hospital speciality admitting patient to ICU.

ADMITTED TO HOSPITAL FROM OTHER HOSPITAL

To be completed **ONLY** if admitted directly to your ICU from another hospital.

THEATRE/RECOVERY	}
A and E	}
WARD	} **ONLY ONE TO BE COMPLETED**
HDU	} location from which admitted to your ICU)
OTHER ICU	}

RECENT PAST HISTORY

a) PREVIOUS ICU ADMISSION

Admission to any ICU within the past six months.

b) PROBABLE INFECTION

Yes if cultures, Gram stains or X-rays were done to confirm a suspected infection; if there is evidence of gross purulence; if therapeutic antibiotics were being administered at the start of intensive care or if there are extensive soft tissue injuries or open wounds in multiple trauma patients. Prophylactic antibiotic therapy does not constitute infection; nor do routine culture specimens.

c) ACTIVE CANCER

Cancer as an active medical problem within six months of ICU admission.

d) CPR WITHIN PAST 24 HOURS

Must include cardiac massage and/or defibrillation.

e) EMERGENCY SURGERY.

Surgery that was required immediately to prevent a life threatening complication.

ELECTIVE SURGERY

may involve a serious problem or procedure, but the patient was scheduled for the surgery.

f) UNEXPECTED COMPLICATION

If no indicate No (N). If yes indicate Yes (Y). Unexpected outcomes may include:-

1) Intraoperative MI.
2) Hypoxia due to airway problems lasting > 4 min
3) Aspiration of gastric contents
4) Cardiac arrest requiring resuscitative efforts
5) Prolonged hypotension (> 10 min MAP <30mmHg).

PREDICTED OUTCOME

The admitting doctor should provide a 'best guess' at the patient's ICU outcome.

CHRONIC HEALTH SCORE

Does the patient have a history of severe, chronic, end-stage disease or is there evidence that the patient is in an immuno-compromised state before this hospital admission? They must conform to the definitions provided on notes attached to the form.

APACHE II: ON ADMISSION

The initial values are the results of tests done up to ONE HOUR BEFORE AND TWO HOURS AFTER admission to the ICU. If more than one measurement was made during this period, use the worst result.

APACHE II

Transient physiological changes that do not reflect the patient's overall condition should not be recorded. e.g. acute, brief hypotension secondary to a dysrhythmia or infusion failure.

TESTS NOT AVAILABLE

If blood tests have not been performed because they are not indicated (e.g. no WBC or creatinine taken in a routine postoperative patient) take last available results before admission. If results are not available AND these results are expected to be normal (e.g. blood gases in patient with good saturation and without respiratory problems) use normal values (score 0 points except for PaO_2 and $PaCO_2$ which are given values of 12.0 and 5.0 respectively and % inspired O_2 of 25%).

FILL IN ALL FIELDS! (CHECK UNITS OF MEASUREMENT)

Temperature

Record the patients core temperature on admission from one of the following sites:- Rectum, Oesophagus, Tympanic membrane, Nasopharynx, Pulmonary artery, Bladder.

Blood Pressure

Use the highest or lowest diastolic pressure to determine which reading to use and record the associated mean pressure.

Heart Rate

Record the patient highest or lowest ventricular rate.

Respiratory Rate

Record the patient highest or lowest repiratory rate, either ventilated, or non ventilated or a combination of both.

pH $PaCO_2$ PaO_2

Use the results from the blood gas measurment with the lowest PaO_2 and note the associated FiO_2, pH and $PaCO_2$.

Hb, Creatinine, Na, K, WBC

Note Units of measurement. See TESTS NOT AVAILABLE.

Acute Renal Failure

Creatinine > 125 μMol/L, ONLY evident in last 48 hours, and associated with urine output < 135 ml over at least one consecutive 8 hour period.

Ventilated

Intubated and machine assisted ventilation including SIMV and PS (pressure support) but not CPAP or nasal mask ventilation.

Sedated

Receiving sedatives, potent analgesics etc. so as to make assessment of GCS difficult or impossible.

Paralysed

Receiving paralysing agents (muscle relaxants) so as to make assessment of GCS difficult or impossible.

Intubated

Presence of tube inserted into trachea through which ventilation or breathing is maintained. This includes tracheostomy.

Glasgow Coma Scale

Assume normal unless evidence otherwise. Thus patients receiving routine postoperative ventilation will usually have a normal GCS. For patients where it is difficult or impossible to assess the GCS, because sedatives or relaxants have been administered, and who may have a reduced GCS (e.g. secondary to head injury, metabolic disorder, hypoxia etc.) use last known values collected when assessment was possible (i.e. prior to sedation/paralysis).

APACHE II: at 24 Hours

The WORST results within 24 hours are scored. The results are of tests performed within the first 24 hours after admission INCLUDING admission values. Therefore the worst scores at 24 hours may be the same as admission scores.

DISCHARGE BEFORE 24 HOURS

If a patient is discharged or dies within 24 hours of ICU admission DO NOT complete 24 hour the APACHE II.

GLASGOW COMA SCALE. (use WORST score within 24 hours)

Assume normal unless evidence otherwise. For patients where it is difficult or impossible to assess the GCS, use last known values collected when assessment was possible. This may be the same as the admission GCS.

APACHE II CODES (see notes attached to form)

These codes describe the MAIN reason for ICU admission.
Thus they answer the questions of why does this patient need intensive care, or, what is happening or may happen to this patient that cannot be managed in an ordinary ward and requires the special services of the ICU.

In most cases patients who are routinely admitted to the ICU after elective surgery are classified according to their surgical procedure. e.g. classification of patients are as follows: after aortic aneurysm surgery;11, after resection of G.I. neoplasm;36.

EXCEPTIONS ARE

1. When a patient is admitted to the ICU NOT because of the surgical procedure, but because of the patient's pre-existing chronic health. e.g. a patient with a long history of congestive cardiac failure (CCF) after a hip replacement. The patient is admitted to ICU because of the cardiac history, NOT the surgery and should be coded for CCF;12.

2. When a patient is admitted to ICU NOT because of the surgical procedure but because of a complication which occurred in the operating theatre or recovery room. e.g. a patient who develops serious cardiac dysrhythmia during a routine procedure (code;18), OR major unexpected haemorrhage (code;21 or 22), OR aspiration during a routine procedure (code;01).

If NONE of the specific diagnoses are applicable to the patient, choose ONE of the physiological system codes (codes 50 - 56) to indicate the primary system whose failure or insufficiency makes it necessary to admit the patient to ICU.

Some patients are difficult to categorise. An example is a patient after major head and neck surgery where airway patency is a concern. The main reason for admission in this case is respiratory observation (code;10).

Cardiac Surgery

This was not considered in the original APACHE II. The following additional categories have been designated.

60 coronary artery bypass grafting (CABG)
61 valve surgery (replacement or repair)
62 combined CABG and valve surgery
63 other cardiac surgery (please specify in admission diagnosis)

TRAUMA

Trauma is "a morbid condition of the body caused by wound or external violence".
Causes include blunt and/or penetrating injury, falls, burns, major chemical, biological or nuclear injury.
Trauma may be blunt or penetrating or both. If both mark both boxes.

RESEARCH

May be used by single or multiple ICU for designated information. The audit office in the ICU of the Royal London Hospital must be contacted by units wishing to use these boxes.

ADMISSION DIAGNOSIS

Please keep this section as brief as possible

A clear, brief, legible description of the reason for the patient's admission and any other relevant information. The database has the ability to search this field for key words. Where abbreviations are used they should be universally recognised and acceptable.

Examples are:

for fracture,
AIDS,
HIV
RTA (road traffic accident/motor vehicle accident/car crash)

PAGE 2
RECORD OF THERAPY

Admission

This covers the period from 1 hour before until 2 hours after admission to the ICU.

Daily Record

To be completed on a daily basis to cover the whole period since the previous Record of Therapy.

15 to Discharge

To cover the whole period from the 14th day after admission until discharge from the ICU.

Nursing Dependency

The WORST dependency score for the period should be completed.

All other categories

For the period over which the Record of Therapy is recorded all relevant fields that apply to the patient are completed. Thus, if within a single recording period, a patient has an oral endotracheal tube, then this is changed for a naso-tracheal tube, which is changed for a tracheostomy, and the patient has a period of spontaneous ventilation before being machine ventilated, then all 5 boxes in the Respiratory Support category will need completion.

Explanations of some of the categories are given below.

RESPIRATORY SUPPORT

Spontaneous Breathing	All modes of ventilation NOT covered by mechanical venitlation. Includes CPAP
Mechanical Ventilation	Any element of ventilatory assist (includes CMV, SIMV, IMV, EMMV, PS, jet/high frequency. Excludes CPAP on its own.

MONITORING

CVP.	for measurement of right sided filling pressures
Arterial Cannula	for measurement of BP
PA catheter	in situ
Cardiac Output	objectively measured (e.g. thermodilution, doppler, impedance)
EEG	any brain wave monitoring, (e.g. formal EEG, continuous monitoring (CFAM), evoked CNS potentials)

RENAL SUPPORT

Haemofiltration	Any continuous extracorporeal renal support.
Haemodialysis	Any intermittent extracoporeal renal support.

CARDIOVASCULAR

Vasoactive Infusion	A **continuous** infusion of any drug that is administered for its effect on the cardiovascular system including inotropes, vasodilators, vasoconstrictors, and infused antidysrhythmic agents. This includes low dose dopamine, dopexamine, nitroglycerine etc.

NUTRITION

Enteral	Nutrition given via the alimentary tract. This excludes clear fluid, tea, coffee etc.
Parenteral	Nutrition administered intravenously. This excludes 5% glucose.

ANALGESIA

Systemic analgesia	Potent pain relieving drugs administered by infusion or intramuscular injection, including patient controlled analgesia.
Regional analgesia	Regional anaesthesia (epidural, spinal, brachial plexus etc.), nerve blocks or large area local infiltration with local anaesthetics and/or opiates for the purpose of providing relief of pain.
Sedation	Continuous infusion or intermittent bolus of sedative agents administered to patients being ventilated.
Muscle relaxation	Neuromuscular blocking drugs (paralysing agents) administered to patients being ventilated. This does not include single doses given to facilitate intubation.

ICU DISCHARGE

Day, Month, Year and Hour (nearest hour 24 hr clock) of discharge from ICU or death in ICU.

STATUS ON ICU DISCHARGE

If ALIVE then complete location to which discharged.
WARD, HDU (high Dependency Unit), another ICU in same or different hospital, or directly HOME.

If DEAD then complete organ donation boxes.
NONE (NO organs donated), or boxes for specific organs donated.

HOSPITAL DISCHARGE OR DEATH

Day, Month, Year of discharge from hospital, or death in hospital after leaving ICU but before discharge from hospital.

STATUS ON HOSPITAL DISCHARGE

ALIVE if left hospital alive, DEAD if died in hospital **after** leaving the ICU.

DISCHARGE SUMMARY

Please keep this section as brief as possible
A clear, brief, legible description of the patient's stay in the ICU.
The database has the ability to search this field for key words. Where abbreviations are used they should be universally recognised and acceptable.

ALL FORMS SHOULD BE RETURNED TO:

Miss Annie Sumner
ITU Audit 0ffice
Royal London Hospital
Whitechapel
London E1 1BB

ANY QUERIES OR DIFFICULTIES-TELEPHONE: 0171 377 7096