THE DESIGN AND FUNCTION OF AN INTENSIVE CARE UNIT

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In 1962 the Ministry of Health circulated a report on progressive patient care which was largely concerned with intensive patient care. Since this report, Regional Hospital Boards have been sympathetic to the establishment of intensive care units, and because of their special skill and knowledge anaesthetists have usually been concerned with the planning and establishment of such units.

Over a year ago a new intensive care unit was built at this hospital (Lancet, 1964) based upon experience gained over two years work in a unit of three beds situated in the existing cubicles at the entrance to a general medical ward. Work in the new unit has revealed very few mistakes that were not already known before conversion of an existing ward; furthermore, the number of visitors inspecting the facilities suggested that a description of the planning and running of the unit might be of interest. The scanty literature available on this subject shows that such units serve many purposes; some can be regarded as being concerned with little more than postoperative care, and in some hospitals there is the duplication of both a medical and a surgical intensive care unit. It is contended that such concepts are in error and are possibly due to the inadequacy of available definitions of the criteria for intensive care.

If the patient requiring intensive care is defined as one requiring mechanical aid to support vital function until the disease process is arrested or ameliorated, then the aims, the planning and control of such units become much simpler. Furthermore, there is no lowering of nursing standards in the acute wards by removal of seriously ill patients not requiring the apparatus and special skills of the intensive care unit. Patients whose diseases are defined in this way may require artificial pulmonary ventilation, haemo- or peritoneal dialysis, cardiac pacemaking, or biochemical correction of severe metabolic disorder; they do not suffer from derangement of but one system. Respiratory failure is often associated with renal impairment, and cardiogenic shock brings both renal and pulmonary ventilation/perfusion ratio defects. The patients can, therefore, no longer be treated satisfactorily in the conventional specialist wards in hospitals, and the greatest chance of survival is provided when treatment is undertaken by a team of medical and nursing staff, with the necessary apparatus and skill, advised as necessary by the consultant referring the patient.

PLANNING CONSIDERATIONS

Patients with conditions so desperate as to require intensive care, withstand movement extremely badly, and considerations such as the siting of the intensive care unit near to the operating theatres, radiographic or other facilities, have been found to be immaterial. The unit should be equipped to deal with the relatively minor procedures—tracheostomy, dialysis, etc., or, on occasions, more major procedures such as Caesarean section—with little inconvenience. The essential requirement is that the unit should be readily accessible from all parts of the hospital.

The load likely to be placed upon such a unit, and therefore the required size, is difficult to assess, for it is directly related to the type of the hospital in which it is located. Estimates have been as low as 2 per cent of medical and surgical patients (Progressive patient care, 1962) or as high as 10 per cent (Saklad, 1964). Experience in this general hospital over three years gives a figure of less than 2 per cent, but this is rising as research reveals more disease conditions amenable to this form of treatment. Although the size of the unit may be conventionally described in terms of "beds", the essential concept is "space", for equipment and manoeuvre. The present unit for a
hospital of 516 acute beds has eight beds but also serves other hospitals which lack similar facilities. The total number of beds in the unit must be limited and most units which fall within the real definition of intensive care are limited in number to between eight and twelve beds. The reason for this must be obvious; there cannot be in one hospital enough staff with the proper skills, or enough apparatus, diagnostic or therapeutic, to care for these patients, and one can only assume that units of forty-eight beds (Darcy, 1964) admit patients who are not in need of or do not receive intensive care. Bates's (1964) surprise that the average patient's stay in some so-called intensive care units is but a few days, is in agreement with experience in this unit, in which the average stay is close to three weeks.

The physical dimensions of the unit are determined by one of two factors. An area may be designated for adaptation in the best way possible. More rarely, the area required can be estimated in advance during a building programme. As a working rule it has been found that the total space assigned for beds in the unit should equal the sum of space for working area and for utility rooms. Two overall designs of units are in use. In one type normal ward bed type of accommodation is provided over a large area (Puddicombe, 1964), with perhaps a limited number of closed single rooms (Edwards, Richardson and Ashworth, 1965). In the second type, the design is based almost entirely on single-room accommodation (Richards, 1964), with another area with sections of two or three beds wherein patients, whose requirements are rather less, can be intensively cared for by fewer nurses.

We are in complete agreement with the view expressed by Bates (1964) that the adoption of the first type of design—"a sort of barn full of expensive machinery"—is a most retrograde step. This "recovery room" approach to intensive patient care is very common and leads to prolonged care of acutely ill patients in large open areas separated only by septic curtains. The reasons usually given in support of this approach are that it is less expensive to build and that more effective surveillance of the patients is possible with fewer nurses. Seldom does one hear it stated that such open areas facilitate cross-infection and make likely a decrease in the available level of intensive care. Patients being treated intensively require constant surveillance and some nursing or medical procedure every minute of every hour of every day. This is best achieved by the use of single rooms. Such an arrangement requires more nursing staff, but effectively prevents depletion of such staff for other purposes.

In experience at this unit, it has been found that the greatest hazard of intensive patient care is cross-infection within the unit. This problem has been most ably reviewed by Kinney (1964), yet cognizance is not always taken of such views. Although some have suggested that an intensive care unit need not be "purpose designed" (Puddicombe, 1964), our own experience proves this to be in error. Thus, in the old temporary unit, death was attributable to cross-infection in nine of eighty-four patients admitted in one year, whereas with largely the same staff in a specifically designed unit this had fallen to two cases out of a first-year total of 168 cases. This adds support to the statement of Kinney (1964) that "in an intensive area not only the grossly septic patient but every patient is an exercise in bacteriological control. Standard procedures for asepsis are seldom effective in a poorly designed unit". The view held by Edwards, Richardson and Ashworth (1965) that septic cases should be excluded from their ward hardly comes within the concept of intensive care, nor does their design allow containment or exclusion of indigenous or airborne bacteria.

Most workers with long experience of intensive care (e.g., Saklad, 1964; Bates, 1964; Kinney, 1964) favour multiple single large rooms, and it was upon this layout that the unit described here was designed. The unit, converted from an existing wartime Emergency Medical Service ward, was designed by the consultant staff and built by the hospital group works department in six weeks at a capital cost of conversion of £5,280.

PLANNING AND DESIGN

It was found that patients generally needed a progressively diminishing amount of intensive care and therefore separate areas were set out for their different needs. Thus, patients are initially admitted to the operating room where facilities for anaesthesia, bronchoscopy, tracheostomy, dialysis or other operative procedures are available. After completion of these procedures the patient can be moved to an intensive treatment room, the design
FIG. 1
Ground plan of Intensive Care Unit.
Scale 1 in. = 18 ft.
allowing for patients to be moved within the confines of the unit on their own beds (figs. 1–5).

The floor space of this operating room is 351 square feet, of which an area of 81 square feet is set aside for storage racks, cupboards and sinks with working top areas. It is essential that all equipment and instruments needed in this area should be immediately and visibly available. The two single-bedded intensive treatment rooms each have a floor space of 216 square feet which is now recognized to be inadequate; 300 square feet would be better. These rooms have an intercommunicating folding plastic door for patient movement only.

After an initial period of treatment, patients have usually recovered sufficiently to be nursed in an open area where observation can be made from the ubiquitous nurse's station, although even in this area activity is frequent enough to allow little time for seated observation. In common with other workers (Saklad, 1964) it is found that there is need for more single rooms and it would be advantageous if the two intensive care rooms were larger. Apart from the serious cross-infection hazard, the bright lighting, activity and noise at each bed dictate single rooms. Bright lighting is necessary to facilitate therapeutic procedures and observations, the actual value being 35 lumens per square foot in the operating room (without the operating light) and 25 lumens per square foot in the intensive treatment rooms. The strip lighting in all parts of the unit has the same colour source so that no false impressions of tissue blood perfusion can be given to staff moving within the unit.

It is known (Clarkson and Robinson, 1962) that acutely ill or curarized patients find their inability to look away from a single light source to be intolerably painful; therefore, a unique form of over-bed strip lighting was designed which could be converted from direct to diffuse by rotating the tube housing to the ceiling.

Much of intensive care equipment is electrical and a large number of socket outlets per bed is essential; there are twelve in the operating room, seven being suspended from the ceiling (so that cables do not trail across the floor), and seven at every other bed. Good chest radiographs are essential to intensive care and this requires at least 90 kV, which is obtained from a Deans mobile unit which requires a separate 30-amp socket. These are easy to install during building of the unit but very expensive to put in as an afterthought. A standby emergency generator is housed near the unit and has been employed twice in the last year. Even so, all ventilation and suction apparatus is capable of hand or foot operation. Piped oxygen was made available throughout the unit, but piped suction was not. This was dictated partly on grounds of cost but also because of the cross-infection hazard. If settle plates are left under unconnected wall suction inlets, colonies of pathogens can be grown. This can be lessened by interposing bacterial filters between the suction bottles on the inlet, but individual electrically operated vacuum pumps are preferred. The individual vacuum pumps used for each patient are changed twice daily and are then cleaned and sterilized with bactericide (Sudol, Prince Regent Tar Co.), the tubing being changed for an autoclaved set. The positive or effluent side of the vacuum pump has a cotton wool bacterial filter and, provided this does not get wet and is changed twice daily, bacterial contamination of the discharged air has not been observed. Although, as in the unit described by Rosen and Secher (1963), an electrical conduit is available at each bed for electronic monitoring to a central console at the nurse's station, feeling is now against such an installation. Electrical thermometers, blood pressure and pulse monitors, electrocardiographic and electroencephalographic devices are used but these are situated at the bedside. In this type of work the only possible and reliable monitor is a highly trained nurse at each bedside, aided as necessary by electronic devices.

It is obligatory, if there is to be success with intensive care, that blood gas analysis, acid-base, metabolic balance and electrolyte values should be immediately available at any hour. There is a certain urgency in these analyses during the hours of darkness. If the possible answer to a problem involves many hours of work, then the analysis may be delayed until the rule-of-thumb clinical assessment and correction has been tried. This method is seldom successful in such a complex and scientific field.

A laboratory is situated at the end of the unit therefore, and apparatus was provided and was, if necessary, designed to enable the junior medical staff themselves to carry out blood gas analysis and similar procedures within 10 minutes. This
FIG. 2
Operating room.

FIG. 3
Intensive treatment room. The overbed strip lighting can be seen.
FIG. 4
View of the intensive care unit, showing the division into separate rooms by the use of Thermoplastic covered walls and the racks for barrier gowns.

FIG. 5
Open area containing two beds and the nurse’s station.
laboratory is also involved with the many research problems posed by intensive care. Thus, estimations of cardiac output, chest compliance, tissue perfusion, external metabolic and electrolyte balance, ventilation/perfusion defects, for example, are all undertaken by this laboratory on patients admitted to the unit. This is an essential part of the philosophy of intensive care. Nowhere can it be more true that the research of today is the routine of tomorrow.

When the unit was built, storage space was known to be inadequate, but as money became available two more rooms were added. One is a large room (600 sq. ft.) for storage of the mass of bulky equipment, and has service benches; the other room (300 sq. ft.) is capable of being kept at 70°F and has a water supply which gives the facilities for ethylene oxide sterilization (Boulbbee et al., 1964).

The existing rooms at the entrance to the ward were converted to provide a comfortable waiting room for relatives (many of whom wait for long periods) and a preparation room in which instruments, suction, cardiac and pacemaker catheters, endotracheal and tracheostomy tubes are packed for sterilization.

The patients' kitchen is largely wasted; patients able to be fed normally have no place in an intensive care unit. The kitchen is used to prepare the intragastric feeds and the staff beverages.

STAFFING STRUCTURE

The administration of the unit is often a subject of controversy (Keats, 1964; Boyd, 1964; Cherniak, 1964); it is believed that patients admitted under the definition given here can only be properly managed by a highly specialized team, and the suggestion that the referring physicians or surgeons could be trained to use the facilities of the unit is ridiculous; these patients require constant surveillance which cannot be undertaken on a part-time basis. The unit team should be primarily responsible for the acute situation which when resolved allows transfer of the patient back to the referring consultant.

Medical staff.

The team consists of a physician and an anaesthetist, either of whom have the sole responsibility for admission of patients. It is sometimes suggested that units of this kind perform a sort of geriatric resuscitation. This is far from the truth; none of us tries to confer immortality nor, on the other hand, is age a bar to admission, provided the condition is remediable and useful patient function can be restored.

There is no doubt that in this work the anaesthesia department is pre-eminent. Respiratory failure is almost always one of the conditions present in patients needing admission to the unit. Other resuscitation techniques are familiar to the anaesthetist, and the ready availability of the 24-hour service of the department ensures that the administrative team must include an anaesthetist.

No resuscitation is worth while without careful diagnosis and control. It is here that the physician on the team is invaluable. There have sometimes been questions as to the advisability of giving "beds" to an anaesthetist. This is difficult to comprehend. Patients alone have beds in this unit, and it is considered that such deliberations as to who has the ultimate clinical responsibility are Victorian and unrealistic. If intensive care is to succeed it requires a working team with patients, and not personalities, in mind. Both of the consultants of the team are always available and hold a combined ward round at noon every day when treatment policy is made or changed. At this round, referring consultants give advice when necessary on the admitting condition, but the handling of the patients within the unit properly remains with the team.

The day-to-day medical control of the patients is undertaken by a senior house officer who has very few other duties. An anaesthetic and medical registrar have a daily duty for the unit, and perform tasks outside the training and competence of the senior house officer. A surgical colleague is always available to perform tracheostomy, peritoneal or haemodialysis, etc.

Some of the success of the unit has been due to insistence that intensive care should be made largely a nursing procedure. If not, lives can be lost as the medical burden becomes intolerable. It has been found that the principles of endotracheal intubation, relaxant therapy in convulsive states, tracheostomy care, pulmonary ventilation and its defects, haemodialysis and cardiac pacemaker, can all be profitably taught to nurses. For this reason, unlike Edwards, Richardson and Ashworth (1964) it is believed that there is no place for a medical officer's bedroom; if one of the
medical staff is in the unit he is working and has no time for sleep. Nurses have been very adequately trained to deal with the rare emergency. More usually, careful monitoring and data collection give ample warning of impending trouble.

**Nursing staff.**

Originally, it was calculated that it would require thirty-five trained nursing staff to allow full cover for the eight beds for eight-hour shifts with allowances for vacations and sickness. It was quickly appreciated that this was unrealistic; such a number of trained staff could not be obtained and eventually proved unnecessary. A shift system was essential, and an almost equal number of trained staff are required at night as during the day; intensive care is a continuous procedure. It proved only necessary however, to have the major proportion of the nursing staff trained and to provide assistance to these by having enrolled nurses and auxiliaries. It is wasteful to use highly trained sisters to change beds and attend to toilet requisites. Furthermore, it has been found perfectly practicable to use enrolled nurses and auxiliaries to watch and record the monitoring of ventilation, compliance, systemic and venous blood pressure, and dialysis. The nursing staff now consists of twelve fully trained sisters, three staff nurses, two enrolled nurses and four auxiliaries. A four-month postgraduate nursing course is held in the unit and these students work in the unit and are paid by the Management Committee. Student nurses have little place in the unit because their knowledge of physiology is usually inadequate to understand the procedures in use, nor are they with the unit long enough to be taught. It is considered that the full four-month course of lectures, demonstrations and experience is needed before sisters are capable of independent judgement within the unit.

The nursing superintendent is male and has two female deputies. In many ways the work of the intensive care ward is ideally suited to the male nurse.

There has been some discussion in the literature on the grave psychological strain this work places upon nursing staff. In our experience there is evidence of some strain, but we think we have overcome this by the tremendous spirit of integrity and comradeship which has arisen. Furthermore, if nurses are taught to understand and are given the responsibility of personally correcting deranged physiology then many of their fears disappear. Most of the nursing staff have worked here for three years.

**Other staff.**

To help with the cross-infection hazard, the unit floors and walls are continually being cleaned, and for this reason the unit has four orderlies and cleaners who also share night duty when the same standards of cleanliness are expected. A technician is employed to look after the mechanical equipment and also to take charge of the ethylene oxide sterilization.

In the last twelve months this unit has treated 168 patients of whom thirty-eight died. By definition of criteria for treatment, without admission every one of these patients would have died; furthermore, of the thirty-eight deaths, eleven were proved at autopsy to have irreparable conditions. It is difficult, therefore, to conceive how Edwards, Richardson and Ashworth (1964) could question whether lives have been saved by the establishment of an intensive care ward. There are certain procedures which have been found essential for success, and perhaps they may be worth recording.

**CONTROL OF CROSS-INFECTION**

In these seriously ill patients with diminished resistance and often a tracheostomy, lung infection with antibiotic-resistant organisms is a real hazard. This has been diminished by the use of single rooms the construction of which did not prove expensive, because the walls are light structures covered with thermoplastic. This design allows thorough cleaning of the rooms and spraying of the walls and floor with a bactericide (Tego; Hough-Hoseason Ltd.). Barrier nursing is practised and each member of the nursing staff only carries out sterile procedures on their own designated patient during their duty shift. Jackets and white coats must be removed on entering the unit; individual gowns and footwear are worn for each room. The removal of outer clothing ensures that such clothes are not placed on racks next to barrier gowns and ensures that visitors are aware that this is a special area with a cross-infection hazard.

Each room in the unit is a complete entity with all the requisite instruments, drugs and solutions.
Traffic between the rooms is prevented as much as possible and for this reason an intercommunication system is being installed.

The major route of cross-infection is via the tracheostomy to the lungs. Attempts have been made to control this route in the following ways:

(1) A most careful aseptic technique must be adopted for aspiration of sputum; this consists of packing the sterile Pinkerton catheters in a nylon envelope which allows the catheter to be fed into the trachea by a "no touch" technique using the outside of the envelope and by the user wearing disposable polyethylene gloves for the manoeuvres of aspiration—e.g., disconnecting the ventilator. Lubrication of aspiration catheters is with a 1/50 Tego solution in saline, each vial of Tego and catheter being discarded after use.

(2) All ventilators are sterilized by ethylene oxide, and when in use are changed for a fresh sterile machine every 48 hours.

(3) All ventilators, except pressure-cycled machines run off the oxygen pipeline, have bacterial intake filters fitted.

(4) Urine collection is by a closed system consisting of a urethral catheter led to a polyethylene container in which is 5 ml of a powerful bacteriocide (Racasan; Racasan Ltd.); this does not interfere with the daily estimations on each patient of urinary electrolytes and total nitrogen.

There have been cases of pneumonia due to Pseudomonas pyocyaneus, which organism is almost certainly a tracheostomy contaminant from the urine collection, but urine collection and analysis is an essential part of the monitoring of intensive care cases. Acute renal failure, so common in these desperate conditions, is, in the writer's experience, largely preventable.

WORKING LOAD

It is firm policy that the bed capacity and the unit staff should not be overloaded. If a patient is admitted to the unit and the staff cannot maintain the strict barrier nursing and give the patient the care and attention necessary for successful resuscitation, then this patient may succumb or become cross-infected; worse still, the patient may infect or diminish the care given to other cases whose progress in the unit had hitherto been satisfactory. This tragic set of circumstances has been seen to occur on several occasions, and this is the reason for the belief that true intensive care units must be limited to eight or ten beds, and the harsh rule of non-admission must be enforced if nursing staffing is inadequate.

During the brief periods when the number of patients in the unit is small, the nursing staff are occupied by review and repair of equipment. The staff are never moved to other work; this leads to discontent. The idea, prevalent in some units, that a nucleus of trained staff should man the unit and that when the working load is high this should be augmented by other nurses, is quite wrong; nurses untrained and inexperienced in this work are much more of a hazard than a help.

| TABLE I |
|----------------------------------|----------------|-------|
| **Primary condition**            | **Admissions** | **Deaths** |
| Cardiorespiratory-renal failure due to cor pulmonale | 48 | 9 |  
| Respiratory failure due to pneumatic consolidation and collapse (including postoperative cases) | 29 | 6 |  
| Poisonings—barbiturate, narcotic or industrial accidents | 22 | 3 |  
| Status asthmaticus | 14 | 2 |  
| Critically crushed chests | 11 | 3 |  
| Metabolic and electrolyte imbalance including diabetic coma and postoperative cases not requiring dialysis | 9 | 2 |  
| Renal failure requiring either peritoneal or haemodialysis | 9 | 4 |  
| Coma due to head injury, meningitis or subarachnoid haemorrhage | 5 | 2 |  
| Pulmonary infarction | 5 | 2 |  
| Status epilepticus | 4 | 1 |  
| Coronary infarction | 4 | 3 |  
| Polyneuritis | 3 | 1 |  
| Eclampsia | 2 | 0 |  
| Congestive cardiac failure due to primary cardiac conditions—mitral stenosis, bacterial endocarditis | 2 | 0 |  
| Tetanus | 1 | 0 |  
| **Total** | **168** | **38** |  

In this table an attempt is made to classify the conditions leading to admission to the Unit in one year (1964–65). This classification cannot be regarded as rigid, as it is usual for more than one system to fail and require mechanical support—e.g., the cardio-respiratory-renal failure of cor pulmonale.
METABOLIC BALANCE

In this country starvation is rare outside hospitals but within hospitals it is most common in the seriously ill patient in need of intensive care. The loss of the lean body cell mass (wasting), which occurs on account of the patient’s inability to maintain a proper dietary intake, is an insult which, on top of their already deranged physiology they cannot sustain. There seems to be a popular misconception that an intake of 5 per cent dextrose, normal saline and Darrow’s solution given intravenously provides the daily requirement of calories and electrolytes. Dextrose solutions were introduced to provide water, not calories. Jones and Peaston (1965), working in the unit, have been able to restore a positive nitrogen balance by giving their formulation for intragastric feeding or intravenously by the use of amino acids, fructose and fat emulsions. It is surprising that at least 2,500 calories per day are required to maintain desperately ill patients in a positive balance, and even curarized patients, although totally inactive, then gain weight during their illness. There is no doubt that intragastric feeding is the easiest route and provides a better metabolic balance; it should be used unless contraindicated by alimentary disorder.

CONCLUSIONS

During the past twelve months 168 patients have been treated in this specifically designed unit, the diseases leading to admission being listed in table I. It is certain that 130 of these were saved by the design and procedures outlined here. The unit has certain faults. There are not enough single rooms and the working floor area in two of the rooms is insufficient. When originally built the ratio of equal storage floor space to working space had to be ignored, but has since been rectified with the addition of the annexe (fig. 6). There is no doubt that Rosen and Secher (1964) are correct in regarding plenum ventilation for an intensive care unit as essential. In the unit, as at present designed, the fight against cross-infection would be easier if air conditioning could have been afforded with a positive pressure air gradient from intensive care rooms to corridor. Welch (1964) has commented on the expense of such a unit and its treatment. This is very real, but can be reduced by a sensible approach to capital outlay, useless long-range electronic monitoring gadgetry being disregarded and pleas made for adequate trained staff who monitor and perform the procedures which get desperately ill patients well again. This must be more expensive than allowing such patients to die, but it is difficult to
see why the expense of such an organization is questioned.

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