T E Oh: Intensive Care Manual

Organization Aspects

Chapter 1: Organization of Intensive Care Units

T E Oh

An Intensive Care Unit (ICU) is a specially staffed and equipped hospital ward dedicated to the management of patients with life-threatening illnesses, injuries, or complications. It has been suggested that the ICU developed from the postoperative recovery room or the poliomyelitis epidemic in the early 1950s, when the use of long-term artificial ventilation resulted in reduced mortality. However, modern Intensive Care or Critical Care medicine is not limited to postoperative care or mechanical ventilation. It is a specialty which evolved from the experience of respiratory and cardiac care, physiological organ support, and Coronary Care Units (CCUs, which were established in the early 1960s). Benefits of centralizing special equipment, staff, and facilities to treat critically ill patients and to avert complications (or reduce their severity) became recognized. The 1970s saw a heightened interest in Intensive Care, with research into the pathophysiological processes, treatment regimens, and outcomes of the critically ill, and the founding of specialty journals, training programmes and qualifications dedicated to Intensive Care. Intensive Care today is a separate specialty, and while some period of training in an ICU is valuable to all specialties, it can no longer be regarded as "part" of anaesthesia, chest medicine, general surgery, or any acute discipline.

Role of the ICU

The definition and delineation of roles of hospitals in a region or ICU Organization area are necessary to rationalize services and optimize the use of resources. Each ICU should similarly have its role in the region defined, which should support the defined duties of its hospital. In general, district and general hospitals require ICUs which involve only monitoring and close observation. An ICU which uses complex management and requires investigative backup should be located in a large tertiary referral hospital of the region. Three levels of ICUs can thus be classified.

1. Level I - District Hospital

A Level I ICU has a role in small district hospitals. It may also be called a "high dependency unit", rather than an ICU. Such a unit allows for close nursing observation and ECG monitoring. Immediate resuscitation is possible, but only short term (i.e. less than 24 h) ventilation should be undertaken.

2. Level II - General Hospital

A Level II ICU is located in larger general hospitals. It is capable of undertaking more prolonged ventilation, and has a resident doctor and access to physiotherapy, pathology and radiological facilities at all times. More complex forms of life support (i.e. dialytic therapies), invasive monitoring (i.e. intracranial pressure monitoring), and investigations (i.e. CT scans) would not normally be provided. It should support the role of its hospital (i.e. area trauma centre).

3. Level III - Tertiary Hospital

A Level III ICU is located in a major tertiary referral hospital. It should provide all aspects of Intensive Care required by its referral role. The unit is staffed by specialist intensivist with trainees, critical care nurses, allied health professionals, and clerical and scientific staff. Support of complex investigations and imaging, and by specialists of all disciplines required by the referral role of the hospital, is available at all times.

Type, Size, and Site of an ICU

Health planning policies may rationalize services by hospitals within a geographical region, so as not to unnecessarily duplicate expensive services. Hence, within each classification, an ICU may not be able to provide Intensive Care for all sub-specialties, or may need to be more oriented towards a particular area of expertise (eg, neurosurgery, cardiac surgery, burns, or trauma). Also, an institution may organize its Intensive Care beds into multiple Units, under separate management control by different specialists, ie, Medical ICU, Surgical ICU, Burns ICU, etc. While this may be appropriate in certain hospitals, Australasian experience has favoured the development of general ICUs. Thus, with the exception of dialysis units, CCUs, and neonatal ICUs, critically ill patients are admitted to the hospital's single ICU, and managed by specialist intensivists. Regions with dedicated paediatric hospitals, of course, have specialist paediatric intensivists.

The number of ICU beds in a hospital usually ranges from 1-2 per 100 total hospital beds. This would depend on the role and type of ICU. Units which routinely admit a large proportion of short-stay, less critically ill patients (eg, postoperative monitoring following elective major surgery), would require more beds than ICUs with "high dependency" beds sited elsewhere in the hospital. ICUs with less than 4 beds are considered not to be cost effective, whereas those with over 12-16 (non-high dependency) beds may be difficult to manage.

The ICU should be sited in close proximity to relevant acute areas, ie, operating rooms, casualty, CCY, labour ward, and acute wards. Critically ill patients are at risk when they are moved. (See Chapter 3, Transport of Critically Ill.) There should be sufficient numbers of lifts, and these, with doors and corridors, should be spacious enough to allow easy passage of beds and equipment - vital points often ignored by planning "experts". Ready access to investigational departments (eg, Radiology and Organ Imaging) and pathology laboratories is also important.

Design of an ICU

There should be a single entry and exit point, attended by the Unit receptionist/clerk. Through traffic of goods or people to other hospital areas must never be allowed. An ICU should have areas and rooms for public reception, patient management and support services (Table 1).

Table 1. *Physical Design of A Major ICU*

Reception Area
- Reception foyer
- Waiting room for visitors (with telephones and beverage facilities)
- Distressed ("crying") / interview room
- Overnight relatives' room

Patient Areas
- Open multi-bed ward(s)
- Single bed isolation rooms
- Central nurse station (including drug storage
- Specialized rooms/beds if necessary, for -
  - procedures/minor surgery (eg, tracheostomy)
  - haemodialysis
  - burns
  - use of bypass or intra-aortic balloon pump machines

Storage and Utility Areas
- Monitoring and electrical equipment
- Respiratory therapy equipment
- Disposables and central sterilizing supplies
- Linen
- Stationery
- Fluids, vascular catheters, and infusion sets
- Non-sterile hardware (eg, drip stands and bed rails)
- Clean utility
- Dirty utility
- Equipment sterilization

Technical areas
- Laboratory
- Workshop for repairs, maintenance, and development

Staff Areas
- Lounge/rest room (with facilities for meals)
- Change rooms
- Toilets and showers
- Offices
- Doctors' on call rooms
- Seminar/conference room

Other Support Areas
- Cleaners' room
- Plant room/alcove.

1. Patient Areas

Each patient bed area requires a *minimum* floor space of 200 ft^2 (18.5 m^2), with single rooms being larger, to accommodate patient, staff and equipment without overcrowding. The ratio of single-room beds to open-ward beds would depend on the role and type of the ICU. Single rooms are essential for isolation cases and (less importantly) privacy for conscious long-stay patients. Positive/negative pressure air conditioning for single isolation rooms are expensive and of unproven value.

Bedside service outlets should conform to local standards and requirements (including electrical safety and emergency supply). Three oxygen, 2 air, 4 suction, and 16 power outlets with a bedside light are optimal for a Level III ICU. How the services are supplied (eg, from floor column, wall mounted, or bed pendent) depends on individual preferences, as each design has its pros and cons. There should be room to place or attach additional portable monitoring equipment, and as much as possible, equipment should be kept off the floor. Space for charts, syringes, sampling tubes, pillows, suction catheters, and patient personal belongings are best arranged in bed dividers. Lead-lining these dividers will help minimize X-ray radiation risks to staff and patients.

All central staff and patient areas must have large clear windows. Lack of natural light and windowless ICUs give rise to patient disorientation and increased stress to all. Since critical care nursing is at the bedside, manning of a central nurse station is less important than in a CCU. Nevertheless, the station should be sited so as to allow all patients to be seen from it. This station usually houses a central monitor, drags cupboards, drugs/specimens refrigerator, telephones, laboratories-linked computer, and patient records. Sufficient numbers of non-splash hand wash basins should be built close to all beds, with each single room having one. There is need for at least one multi-display X-ray viewer in each multi-bed ward. Proper facilities for haemodialysis, such as filtered water, should be incorporated.

2. Storage and Supporting Services Areas

Most ICUs lack storage space. Storage areas should total a floor space of about 25-30% of all the patient and central station areas. Frequently used items (eg, IV fluids and giving sets, sheets, dressing trays, etc) should be located closer to patients than infrequently used or non-patient items (eg, more sophisticated monitoring devices).

Floor areas for supporting services (Table 1) should make up about 20-25% of the patient and central station areas. Clean and separate utility rooms must be separate, each with its own access. Disposal of soiled linen and waste must be catered for, including contaminated items from infections patients. Facilities for estimating blood gases, electrolytes, haemoglobin, haematocrit, and osmolality, with a microscope being available, are usually sufficient for the Unit laboratory. Larger ICUs may require a satellite pharmacy within the Unit. A good communication network of phones/intercoms is vital to locate and inform staff quickly. An special paging code eg "1111" will enable instant summoning of ICU staff in emergencies. Adequate arrangements for offices, doctor on-call rooms, staff lounge (with food/drinks facilities), wash rooms, and teaching complete the Unit.

Equipment

The quantity and level of equipment will depend on the role and type of ICU. Level I and II ICUs will obviously require less than a Level III Unit (Table 2). For example, a 2-channel bedside monitor should suffice for a small district hospital ICU, whereas a major teaching hospital ICU should be equipped with monitors able to display at least 4 physiological signals. Monitoring devices and ventilators are discussed in Ventilators, Lung Function Tests, Haemodynamic Monitoring, and Neurological Monitoring. Equipment should be chosen by experienced intensivists, as so often, much expensive but inappropriate or unsuitable equipment is bought by inept or less knowledgeable people.

Table 2. *Equipment in A Major ICU*

Monitoring

- Bedside and central monitors
- 12-lead ECG (paper) recorder
- Intravascular and intracranial pressure monitoring devices
- Cardiac output computer
- Pulse oximeters
- Pulmonary function monitoring devices
- Expired CO_2 analyzers
- Cerebral function/EEG monitor
- Patient/bed weighers
- Temperature monitors
- Enzymatic blood glucose meters

Radiology

- X-ray viewers
- Portable X-ray machine
- Image intensifier

Respiratory Therapy

- Ventilators, bedside and portable
- Humidifiers
- Oxygen therapy devices and airway circuits
- Intubation trolley (airway control equipment)
- Manual self-inflating resuscitators
- Fibreoptic bronchoscope
- Anaesthetic machine

Cardiovascular Therapy

- Cardiopulmonary resuscitation trolleys
- Defibrillators
- Temporary transvenous pacemaker
- Intra-aortic balloon pump
- Infusion pumps and syringes

Dialytic Therapy

- Haemodialysis machine
- Peritoneal dialysis equipment
- Continuous arterio-venous haemofiltration sets

Laboratory

- Blood gas analyzer
- Selective ion (electrolyte) electrode analyzers
- Osmometer
- Haematocrit centrifuge
- Microscope

Hardware

- Dressing trolleys
- Drip stands
- Bed restraints
- Heating/cooling blankets
- Pressure distribution mattresses
- Sterilizing equipment (eg, autoclave and glutaraldehyde bath).

Staffing

The level of staffing also depends on the type of hospital. A large hospital ICU requires a large team of people (Table 3).

Table 3. *Staff of A Major ICU*

Medical

- Director
- Staff specialist intensivists
- Junior doctors

Nurses

- Charge Nurses
- Nurses
- Nurse educator

Allied Health

- Physiotherapists
- Pharmacist
- Dietician
- Social worker
- Respiratory therapists

Technicians

Secretarial

Secretary

Ward clerk

Radiographers

Support Staff

Orderlies

Cleaners.

1. Medical Staff

Career (full time or near full time) intensivists are responsible for the clinical management of patients referred tot he ICU in countries which have developed Intensive Care medicine as a separate specialty or subspecialty. The ICU Director is one of such specialists. Hospitals of countries without discrete training programmes in Intensive Care or recognition of the specialty, may adopt a multidisciplinary "management-in-consultation" concept. In this way, a team (usually anaesthetists) looks after the day-to-day and emergency aspects, but co-manages the case with the primary specialist. Whilst appearing democratic, lines of responsibility may at times be unclear, and expert coverage or acquisition of knowledge or experience may not be optimal if individuals do not spend too much time in the Unit.

Junior medical staff in the ICU may be Intensive Care trainees, but should ideally also include trainees of other acute disciplines (eg, anaesthesia, medicine, and surgery). For a Level II or III ICU, it is imperative that adequate supervision of junior doctors, with ready access to specialists, is present.

2. Nursing Staff

The level of nursing staffing shall also depend on the type of ICU. Major ICUs should have a majority of their nurses experienced in critical care nursing. Courses or training programs in critical care are valuable if creditable. The actual total numbers of nurses for an ICU must take into account night shifts, and annual, sick, or study leave. At all times, all critically ill patients must have 1:1 nursing. Occasionally, very unstable patients requiring complex therapy (eg, dialytic therapy) requires 2 nurses most times. Practical staff numbers can be derived from work statistics and types of patients.

3. Allied Health

Major ICUs should have 24 hour access to physiotherapists and radiographic services. Access to other therapists, dieticians, and social workers should also be available. A dedicated ward clinical pharmacist is invaluable. Respiratory therapists are allied health personnel trained in, and responsible for, the equipment and clinical aspects of respiratory therapy, a concept well established in North America, but not Britain, Europe, and Australasia. Technicians, either as a member of the ICU staff, or seconded from biophysics departments, are necessary to service, repair, and develop equipment.

4. Other Staff

Provision should be made for adequate secretarial staff, ie, secretaries and ward clerks. Transport and "lifting" orderly teams make much sense, reducing physical stress and possible injuries to nurses and doctors. If no mechanical system is available to transport specimens to the laboratories (eg, air pressurized chutes), sufficient and reliable manual labour must be provided to do this day and night. Contact is made with the local chaplains, priests, or officials of all religions, when there is need for relevant services. Their role in counselling and consoling distressed relatives is invaluable.

Operational Policies

Clear cut administrative policies are vital to the functioning of an ICU. These include clinical management responsibilities (see above), admission, discharge, and referral policies. Lines of management must be delineated for all staff members, and their job descriptions defined. The Director must have final, overall authority of all staff and their actions in the Unit, although in other respects, each group may be responsible to their respective hospital heads, eg, Nursing Director.

Policies for the care of patients should be formulated. They should be unambiguous, and periodically reviewed and changed if necessary, and be familiarized to all new staff. Certain policies are universally applicable, eg, antibiotic policies and compulsory hand washing before and after examining patients. Others depend more on local situations and personal beliefs, eg, donning gowns and shoes before entering the ICU, a ritual not proven to reduce cross infection.

Continuing Education and Research

Major ICUs, like any teaching hospital department, must have on going academic programs. There should be regular meetings to review clinical management, journals, and new developments. Audit and peer review exercises will document and improve the quality of care. Teaching programs must be instituted for trainees, nurses and other health care workers. Research has to be encouraged and pursued.

Ethics in Intensive Care

Professional ethics in patient care, research, and conduct towards medical and other professional colleagues must be scrupulously upheld. In addition, ICUs with their high technological and life support systems, are vulnerable to legal, moral, and ethical controversies of "euthanasia" or over-enthusiastic treatment; extreme opposite convictions of which are represented by the "right-to-life" and "voluntary euthanasia" groups. Considerable difficulties are caused by public misconceptions of medical practices, and differences in the use and interpretation of terminology, which are not helped by irresponsible public media.

Euthanasia

The acceptance of death by the diagnosis of brain death from brain stem function tests are now well established. (See Chapter 42, Brain Stem Death.) Terminating life support on a patient with proven brain death should no longer have any legal or ethical implications. Euthanasia, on the other hand, can be viewed as three types:

1. "voluntary euthanasia", or intentional killing of those who have expressed a competent, freely made wish to be killed;

2. professionally assisting suicide; and

3. homicide by agreement of all parties except the subject, who may or may not survive intensive therapy, when death is not imminent (i.e. newborns with congenital defects and ventilated patients with chronic debilitated diseases).

Advocates of euthanasia, as specified above, may argue that it is morally justified in certain cases, as the ultimate outcome is "good" and "best" for the patient. However, euthanasia cannot be ethically justified, because any direct and active action to terminate life, *with known intent*, is always wrong.

Withdrawal or Withholding of Treatment

The withdrawal or withholding of treatment which sustains or prolongs life has been unfortunately called "passive euthanasia", a term which is both inaccurate and misleading. Allowing a patient to die by withdrawing treatment proved to be of no benefit, or not starting treatment judged to be of no benefit, when death is usually inevitable (albeit not always invariable), cannot be morally or ethically equated with euthanasia, as the intentions are different.

Legal Considerations

Probably in nearly al countries (certainly in Canada, Britain, Australia, and New Zealand), there is no provision to allow euthanasia ("mercy killing") or the assistance of suicide to be legally treated differently from homicide. Law reform enquiries have examined the rights (to die) of competent subjects with incurable terminal or incapacitating illnesses. However, some considerations pose difficulties, such as possible personal motives, wrong or incompetent diagnosis and/or prognosis, the degree of intolerable incapacitation, and the assessment/validation of the patient's mental competence. Consent of the patient to undergo euthanasia cannot be relevant, as it is a consent to an unlawful act. The rights of incompetent patients for euthanasia cannot be relevant, as it is a consent to an unlawful act. The rights of incompetent patients for euthanasia or to refuse care, are even more complex. On the other hand, withdrawal or withholding of treatment was found to be different by a recent Australian enquiry into dying, in that "the non-application of medical treatment does not in itself constitute the cause of death, where a medical practitioner is acting in good faith".

In the USA, while euthanasia is illegal, it is now established that competent patients have a legal right to refuse medical care. This right to "death with dignity" has at times been extended by courts to incompetent patients. Most States have adopted "living will" laws permitting patients to provide written instructions about what medical interventions they would or wound not want, if they become incompetent. As these "wills" are made in advance without knowing the nature of one's future incapacitation (or indeed that it will occur), the laws, by necessity, lack precision. Some laws require certification of the competence of the subject, and others apply only to patients with a "terminal" condition or when death is imminent. Consequently, difficulties in interpretation of the legislations arise. One other difficulty is that the law may be interpreted to indicate that all medical measures must be applied to those patients who have not made a living will.

Most US States also have laws covering an enduring power of attorney, which nominates another person ("healthy proxy") to make treatment decisions on one's behalf, in the event of incompetence. This concept could allow for the cessation of unwanted treatment, even life sustaining treatment, but could not involve the possibility of an illegal act, such as direct killing. The legal status of the above living will and enduring power of attorney documents are largely untested outside the USA, but these issues should not be confused with euthanasia and the associated ethical difficulties of doctors who directly bring about the death of their patients.

Practical Considerations

There are occasions in the ICU when all treatment, including the most sophisticated and expensive, do not influence outcome. Apart from the financial cost to the community, the emotional cost to the relatives (as well as staff), to keep the patient alive "to the very end", is heavy. Family and friends become hostages to technology, when life support treatment, instead of saving a life, delays inevitable, imminent death. In such cases, intensivists should consider the appropriateness of continuing or starting "aggressive" treatment and examine the ethical basis of their decisions. Not every patient requires an "all out" effort. At all times, consideration must be given to the best interests of (a) the patient, (b) the family, and (c) the community in that order.

Communication with the relatives is all important. Frank and honest discussions must be held with them. The clinical situation, treatment given, and judged prognosis must be explained clearly, avoiding medical terms. Their views and opinions must be sought and respected, but they must never be placed in a position where they are (or feel that they are) forced to make a treatment decision affecting the patient. This may otherwise lead to feelings of guilt, bitterness, or confusion if the patient dies. Also, the patient's best interests may not be represented by the relatives, especially if there are feuding family factions. The ICU staff must have unwavering patience in dealing with the relatives, some of whom react differently under the stress. Some relatives want "everything" to be done. Others may become aggressive. Commonly, some do not accept the situation, and do not appear to retain repeated explanations of bad prognosis. It is good practice for the same one or two staff members (eg, intensivist and bedside nurse) to communicate with each set of relatives. This will help promote comfort and trust, and avoid misunderstandings in communications. Any personal biases expressed in informal loose talk by any staff member, is irresponsible and unethical.

Chapter 2: Predicting Outcome of Critical Illness

J R Frisby

With the technological expansion of the 1980s has come the increasing expense of caring for the critically ill. The concept of outcome prediction has, in part, emanated from society's need to rationalize limited financial resources, and to optimize the care of those patients who have a reasonable chance of meaningful recovery from critical illness. Within this broad concept, come the difficult ethical considerations of when to limit resources in particular, seemingly hopeless cases. Clearly, the problem extends beyond simple statistical analyses. Aspects of medical decision making, as well as illness severity scoring systems, are thus becoming increasingly important. This discussion will focus on adult Intensive Care patients only.

"Whole Patient" Considerations

When assessing possible outcome from critical illness, the following patient variables should be considered:

1. Age

In general, increasing age is associated with a reduced ability to recover from a critical illness. The reasons include increased propensity for the initial life-threatening illness, reduced physiological reserve, and the development of complications during treatment. The concept of "biological versus chronological" age has some merit, in that it attempts to quantify the overall health status of the individual through "age". The elderly patient has a higher incidence of cardiovascular and respiratory disease, which makes the likelihood of intercurrent myocardial infarction and respiratory failure higher. At the extremes of age, a non-specific state of immune deficiency exists either through poor nutrition, hormonal changes, or other mechanisms. These not only increase the likelihood of acquiring severe infection de novo, but also increases the incidence of developing nosocomial infection whilst in the ICU. All these factors will adversely affect outcome.

The elderly have an increased incidence of social isolation, often living alone with little home help. Their admission may be directly related to this. In addition, a longer period of convalescence may be necessary. As a result of critical illness, an elderly patient may have little or no chance of returning to independent existence. These issues are relevant to overall management plans.

2. Past Illnesses

The nature and severity of a pre-morbid medical condition will affect outcome. A detailed understanding of the patient's past illnesses is of major importance. Preexistant illnesses will reduce physiological reserve. For example, the emphysematous patient who is dyspnoeic on minimal exertion, is less likely to tolerate long-term assisted ventilation without barotrauma and infectious complications.

Patients with cancer and haematological malignancy require special consideration. The prognosis of many cancers thought to be incurable 5 years ago, are not excellent, with good long-term survival. However, complications from intensive chemotherapy (such as infections from neutropenia and bleeding from thrombocytopenia) may affect outcome. Whilst the outcome for critically ill cancer patients is worse than that for a comparable group without cancer, it is important to ascertain the nature and extent of the underlying disease, and the likelihood for long-term survival from that disease alone. Consultation with a clinical oncologist/haematologist is helpful.

3. Current Illness

The severity and extent of the current illness has, obviously, a major impact on outcome. Many diseases can be accurately staged, and prognostic information obtained from this assessment. Scoring systems are applicable in many cases (see below). For example, a severe head injury who presents in coma and with a low Glasgow Coma Score will, in general, do less well than one who presents with minimal neurological abnormality. An understanding of the pathophysiology is important to both management and outcome. When the current illness is considered, morbidity associated with treatment, must also be borne in mind.

4. Response to Treatment

Depending on the illness, the likelihood of recovery may be reasonably assessed after a defined period of time. For instance, the outlook for adult patients in persistant coma 4 days following cardiac arrest/hypoxic encephalopathy, is uniformly bleak. However, time frames like this correspond to specific clinical entities. The above bleak outlook, for example, cannot be applied with accuracy to all head-injured young adults 4 days after injury. Recovery and response to treatment vary according to the patient, the disease and the resources available. With adequate understanding of each case, it is reasonable to set a time, at which absence of clinical improvement would indicate a reassessment of further aggressive treatment. It is well recognized that prolonged Intensive Care is associated with increasing mortality/morbidity, as a function of the severity of illness.

5. Social Circumstances

Consideration of the patient's social situation will often give insight into the nature of the medical problem. For example, treatment and long-term outlook will be limited by the incompetence of the chronic alcoholic to care for himself following hospital discharge, and who is not a candidate for social support services. A similar situation involves the chronic, multi-medication dependent, but non-compliant patient.

It is important to consider the patient's family when making decisions regarding Intensive Care. (See Chapter 1, Organization of Intensive Care Units.) The nature and prognosis of the illness should be clarified. Time may be required to allow close relatives to form realistic expectations and goals, and repeated discussions are often necessary.

6. Future "Quality of Life"

The most difficult area in outcome prediction is the estimation of the quality of life, should the patient survive. High probabilities of permanent, severe physical or mental incapacitation, and subsequent intolerable distress, may influence continuation of "all out" aggressive therapy. Unfortunately, it is extremely difficult to discern the extent of disability the patient may wish to tolerate. Care must be taken to avoid using one's own perceptions without consideration for the patient's and family's viewpoint.

Resources

In today's society, health care resources are finite. Decisions are necessary regarding the admission of patients unlikely to do well into over-burdened ICUs. Clear admission and discharge policies are necessary. (See Chapter 1, Organization of Intensive Care Units.) Prognostic stratification, based on numerous criteria can help guide admission or treatment decisions.

Illness Severity Scoring Systems

Several scoring systems have emerged over recent years, in an attempt to statistically quantify the relationship between disease severity and outcome. Scoring systems are in common practice in many areas of medicine. Most forms of malignant disease are staged according to extent of tumour, and clinical staging correlates with survival and the response to treatment. The major scoring systems are discussed below.

Acute Physiology and Chronic Health Evaluation II (APACHE II)

The APACHE II severity of disease classification was devised by Knaus in an attempt to stratify prognostic groups of critically ill patients, as well as determine the success of different forms of treatment. The original APACHE score was based on 34 physiological parameters (the Acute Physiology Score (APS)), and a subjective assessment of the severity of chronic, intercurrent disease, but was found to be too cumbersome for routine clinical use. APACHE II was developed as a simplified, clinically useful classification, using 12 easily measured variables (APS) and an evaluation of pre-morbid health. Although debate has occurred on the timing of assessment, it is recommended that the worst score over the first 24 hours following ICU admission be used. The 12 parameters comprising the APS are:

1. Temperature (°C)
2. Mean arterial pressure (mmHg)
3. Heart rate (beats/min)
4. Alveolar-arterial oxygen gradient (A-aDO_2) if fractional inspired oxygen (FIO_2) is 0.5 or greater or PaO_2 if FIO_2 is less than 0.5.
6. Arterial pH
7. Serum sodium (mmol/L)
8. Serum potassium (mmol/L)
9. Serum creatinine (mg/100 mL)
10. Haematocrit (%)
12. Glasgow coma score (GCS).

Depending on the degree of derangement, a weighted score is assigned to each parameter (APS). Unlike the original APACHE, all parameters should be entered, except perhaps arterial pH and creatinine in routine postoperative monitoring cases, where it is assumed that these will be normal. Care must also be exercised in correctly recording GCS of 15, when neurological problems are unlikely to exist. The GCS is a subjective assessment, unlike the other criteria, and is therefore subject to potential bias.

Points are also assigned for increasing age, emergency postoperative or nonoperative admission, and if a history of severe organ system insufficiency exists. Within the physiological parameters defined above, double weighting is assigned to derangements of serum creatinine in the setting of acute renal failure in the critically ill. The maximum possible score is 71, although nearly all patients have scores much lower than this. Increasing scores correlate with higher hospital mortality, at each 5 point increment, across a wide range of diseases. It should be recognized, however, that the APACHE score reflects the severity of physiological derangement within a single diagnostic category, at a single point in time. Differing disease states have intrinsically differing outcomes, most notably diabetic ketoacidosis, where a profound physiologic derangement on admission is not predictive of subsequent mortality. Similarly, a high initial APACHE II score in postoperative coronary artery bypass patients need not result in a high mortality. In contrast, similar scores in patients with septic shock are associated with a much higher fatal outcome. However, within both these groups, an increasingly high score reflects a poorer outcome. Problems also arise when the patient's disease is difficult to categorize. For example, should a dilutional coagulopathy in the setting of hypovolemic shock due to poly-trauma be classified as haematologic, cardiac or traumatic? The inability to account for the development of multi-system failure after subsequent admission remains another problem.

It is recommended that disease-specific mortality predictions be based on at least 50 patients in each diagnostic category, and at least 20 patients should be in the least-frequent outcome category. This will minimize potential chance results. Those patients who can only be classified by specific (multi-) organ system dysfunction (as opposed to specific diagnosis) may be more difficult to compare.

It is argued that expected death rates based on the APACHE II score may be compared to actual death rates as a means of judging therapeutic efficacy. The score may also be used to assess the effects of different treatment modalities. Although these concepts are tenable, care must be used in the application of raw scores across different hospitals and health care systems, each with varying practices and biases. Further studies are required to assess these important considerations.

Whilst the score was not designed originally to influence patient management decisions, it may provide the clinician with more information to guide future decisions, particularly with respect to the probability of hospital death. An APACHE II trend analysis may be more appropriate, utilizing sequential APACHE scores at fixed intervals (eg, daily), and noting the rate of change relative to the last score. It should not, however, replace balanced medical assessments, based not only on the APACHE II score, but also on the less-tangible concepts described earlier. There is sufficient APACHE II score overlap in survivors versus non-survivors in many diseases, to be cautious in its widespread application as a predictor of mortality.

Sickness Scoring

Several variants of the APACHE II score have been developed in an attempt to enhance its prognostic ability. One such system is Bion's "sickness score" (SS). Using a APACHE II "template", the following modifications are made:

1. Units are converted to SI units.

2. Haemoglobin concentration is used rather than Haematocrit.

3. Oxygenation is assessed using a ratio of the FIO_2 and PaO_2.

4. The "chronic disease" category is redefined to include conditions associated with loss of independent self-care.

5. Clinical judgment is used in the application of the Glasgow Coma Score.

6. Haemodynamic instability is assessed to reflect overall abnormalities rather than transient, perhaps drug-induced, changes.

7. Daily scores are charted, to assess response to treatment.

Using these guidelines, periodic neurological and cardiovascular abnormalities due to sedative drugs could be "buffered" in the overall scoring analysis. It was also postulated, as the ICU is a place where acute physiological disturbances could be remedied, that the response to treatment was important as a prognostic indicator.

Increasing SS was associated with higher mortality, as was a sequential rise over time, indicating a lack of response to treatment. The admission SS correctly identified 80.6% of survivors and 70.4% of non-survivors. Trend analysis enhanced the predictive accuracy. However, decisions t continue or withdraw Intensive Care should be based on clinical judgement, with an appreciation of the changing SS as another marker of disease severity.

Simplified Acute Physiology Score (SAPS)

Le Gall reduced the former 34-variable APACHE score to 14 easily definable parameters, similar to the current APACHE II score. Minor variations to account for ventilated patients were made. The conclusions were similar to results obtained from the APACHE II and SS studies. With increasing SAPS, mortality increased progressively, although disease-related mortality/SAPS correlation has, to date, not been published.

Mortality Prediction Models (MPMs)

Lemeshow devised MPMs based on multivariate statistical analysis of a large cohort of adult general Intensive Care patients. The predictive ability of these models to assess mortality risk is similar to the scoring systems cited above. Serial assessments may be more accurate in predicting future mortality. The system may be more elegant, in that admission diagnosis is not required. A series of true/false questions are answered, and these are weighted according to their individual contribution to mortality. The predictive ability of sequential MPMs is approximately 74-80%, which still leaves enough inaccuracy to limit its usefulness as a tool for making decisions affecting outcome without resort to clinical judgement and experience.

Therapeutic Intervention Scoring System (TISS)

TISS was developed in 1974, and updated in 1983 in response to changing technology and new procedures. By assigning a score to those procedures performed on patients in the ICU, an indicator of the severity of illness, and perhaps prognosis, could be inferred. In addition, the establishment of the appropriate nurse/patient ratio and staff/bed utilization could be established.

It was suggested that a competent ICU nurse could handle 40-50 TISS points/day. The number of therapeutic interventions on a given patient would, by necessity, be dependent on the type of care given, and the implied need for such procedures such as invasive monitoring and assisted ventilation. An unacceptably high TISS in the setting of continued active treatment would suggest that discharge from the ICU was inappropriate.

Whilst TISS has been shown to be valuable from a unit administration standpoint, its inability to predict death in an individual mitigates its use as a serious prognostic indicator. TISS points are physician-dependent. As medical practices are different at each institution, so are the potential therapeutic interventions performed.

Other Scoring Systems

Whilst multivariable scoring is helpful in the critically ill, a unisystem disease severity score may, by itself, be of major prognostic importance, even in the setting of multisystem disease. Common scoring systems include the injury severity score (ISS) (see Management of Severe and Multiple Trauma), Glasgow coma score (GCS), trauma score and the abbreviated burn index. For instance, a head-injured patient with a poor GCS will have a poor outcome, independent of the development of a small myocardial infarct. Other concurrent medical problems will usually increase the likelihood of a poor outcome, if they are functionally important or have an unfavourable prognosis by themselves. This requires an understanding of the individual importance of particular disease states and the need for specialist Intensive Care physicians with a broad background in a number of medical specialties.

Comparison Between Different Scoring Systems

To date, very little work has been done to compare the above systems. Analysis of 1997 patients using the Acute Physiology Score (APACHE without the chronic health evaluation), SAPS, and MPMs, showed little difference between any system in predictive ability over a wide range of scores. All systems showed that increasing severity of physiological derangement was associated with increased mortality. The MPM was, however, based only on a single assessment on admission, and not on serial assessment. It remains to be seen whether sequential MPM analysis is superior.

Chapter 3: Transport of the Critically Ill

J E Gilligan

Therapy and investigation of the Intensive Care patient may require movement, eg, to the operating room, CT Scanner, angiography suite, or another medical centre. The movement of a patient with complex therapy in progress presents major problems and risks. Consequently, the patient may lose vital haemodynamic and respiratory stability and be in poor condition for any planned procedure. Adequate care of the sick patient in motion remains a commonly neglected area of Intensive Care. The involvement of intensivists or anaesthetists in mobile Intensive Care is emphasized as unqualified or experienced staff perform poorly. Safe transfer of the critically ill is facilitated by defining the problems of the patient, the transport environment and those of staff. Factors which contribute to unsafe movement may be categorized as follows:

1. Difficulty in providing compact and portable life support and monitoring equipment which is also compatible with equipment at both ends of the journey.

2. Multiplicity of objects attached to the patient.

3. Increased possibility of mishaps (eg, endotracheal tube dislodgment).

4. Poor tolerance of the sick patient to abrupt movement, lifting and vibration.

5. Unfavourable climate and weather conditions encountered in transit, and other physical difficulties presented by inadequate corridors, lifts and vehicles.

6. Deficiencies in accompanying staff skills and numbers.

7. Failure to realize that the staff have two different roles and to co-ordinate these caring and moving teams.

Achieving Safe Movement

General principles in achieving safe transport are similar, whatever the location. They are:

1. Explaining to the patient (when communication is possible) what is planned.

2. Stabilizing the patient optimally before transportation.

3. Moving the patient in a planned, unhurried fashion.

4. Maintaining in transit the stability previously achieved.

5. Liaising adequately with the receiving staff.

There are differences in detail, depending on the type of movement being undertaken. It is thus helpful to consider the following key requirements to enable safe movement of the patient:

1. *Planning/communications.*

2. *Personnel:* the number and type of staff.

3. *Properties:* the equipment needed which may be divided into
   (a) the life support and other treatment devices, and
   (b) the monitoring systems.

4. *Procedures:* resuscitative or surgical, which may be required before transport.

5. *Passage:* the route and mode of transport and how it may affect the patient.

The different types of movement may be classified under the categories below:

1. *Intra-mural:* between departments or wards of a hospital.

2. *Extra-mural:* transport beyond the boundaries of a hospital; these may be three types:

(a) *Pre-hospital* or primary transport: when Intensive Care / Anaesthesia / Accident & Emergency staff combine with ambulance officers/paramedics to safely deliver a critically ill patient from an accident site to definitive care.

(b) *Inter-hospital* or secondary transport: when transfer to a second hospital becomes necessary, eg, from rural to city hospital. Another variant of inter-hospital transfer is:

(c) *International or long distance*, eg, greater than 5000 km. Evacuation over this distance may have additional requirements.

The term "retrieval team" has been applied to mobile Intensive Care teams provided by a major centre.

3. *Other types:* these are:

(a) Neonatal transport (usually inter-hospital).

(b) Hyperbaric transport (movement of a patient in a mobile recompression chamber).

(c) Movement of ICU patients from a fire threat.

(d) Counter disaster situations requiring attention to and evacuation of many patients on site (eg, a train crash).

Intra-Mural Movement

This is the commonest type of movement for ICU patients.

Planning

If possible, the patient should be shifted at a time and along a route likely to produce minimal delay. A team member is sent ahead to commander lifts and clear corridors. Plans are agreed with all parties beforehand to avoid delays (eg, waiting in a corridor until a CT scanner becomes available).

Personnel

Skilled medical and nursing staff should accompany patients on life support. There should be enough strong staff to physically move the patient. Lifting onto an operating table, for example, requires 5 people. Tasks are apportioned accordingly:

(a) Orderlies to push and steer the bed/trolley.

(b) Nursing and medical staff to supervise, continue therapy en route, and transfer care at the receiving end.

Procedures

Procedures to stabilize the patient (eg, intubation) must be carried out prior to transport.

Properties

Compact equipment is carried on the bed or by a staff member. Often, the mass of equipment may require a separate trolley. A trailing IV pole on wheels is unstable and should be avoided.

1. Life Support and Other Treatment Devices

(a) *Artificial Ventilation*

Manual ventilation is feasible for short periods. Lightweight or portable gas driven (eg, Oxylog, Bird Mk 14) or battery powered (Bear 33, LP 6) ventilators free staff for other tasks. However, they lack the versatility of ICU ventilators. (See Ventilators.) Hence patients with poor lung compliance or severe bronchospasm may suffer worsening gaseous exchange, if the transit or destination (eg, operating room) ventilator is less effective. Transit ventilators requiring both supplies of oxygen and air have obvious disadvantages. Using oxygen alone, with room air entrainment (eg, Oxylog), the restricted range of FIO_2 (1.0-0.5) is acceptable for short periods. A self-inflating bag and a spare ventilator exhale valve should be carried, in case the oxygen supply or breathing circuit fails. Humidification by heat and moisture exchangers is preferable to bulky, conventional humidifiers. Battery powered or a venturi-system suction devices are available. The latter is driven by compressed gas and may seriously deplete the supply needed for ventilation. Positive end expiratory pressure may be achieved by either spring loaded or ball valves; the latter, however, need to remain vertical to be effective.

(b) *Pleural drainage*

"Flutter" valves (eg, Heimlich) are the most compact but may not be suitable for situations other than transport. Underwater seal drainage (UWSD) systems are awkward to transport but allow pleural air leaks to be visualized. The reservoir has to be secured from tilting and at least 30 cm below the patient, to minimize aspiration of air and drainage fluid into the pleural cavity. Plastic should be used, as shattering of glass may cause loss of the seal. Staff should not clamp the drainage tube when lifting the patient, because of the risk of producing tension pneumothorax, especially if a bronchopleural fistula is present.

(c) *Urine and Wound drainage*

Any extensive diuresis or other fluid loss, especially on an extended absence from the ICU, should not go unattended.

(d) *Defibrillation*

Combined monitor/defibrillators are convenient for transport. Standard defibrillation procedures are discussed in Cardioversion and Defibrillation.

(e) *Pacemakers*

Transvenous types constitute an example of a cardio-invasive line (see below). External cutaneous pacing has possible short term emergency use. (See chapter 9, Cardiac Pacing.)

(f) *Intravenous Fluids*

Well secured, patent venous lines are essential, preferably away from wrists or elbows. Luer-lock junctions reduce the disconnection risk. For short trips, plastic infusion bags may be turned off and placed on the bed. However, when restarting flow, entrained bubbles need to be expelled. Glass bottles are hazardous because of shattering when dropped. Assured supply of fluids plus pressor infusion sleeve bags are necessary. If blood transfusion is anticipated, checking of available blood should be completed beforehand. Blood warming by water bath is impractical. A dry heat warmer is used if required.

Gravity feed IV systems cannot reliably infuse constant rates. An infusion pump should have spare charged batteries if battery endurance is less then twice the expected duration of the trip. The pump should be capable of operating on mains power and in any position (vertical or horizontal). In the event of battery failure, a method of reverting to gravity feed is desirable. Spring loaded or mechanical clockwork devices lack the range of infusion rates of electronic devices.

IV drugs should be checked, drawn up and labelled beforehand. To reduce the hazards of needlestick injuries, injection should be into an IV line, and not directly into a vein. Used needles should not be resheathed but discarded into a small rigid "sharps" container.

Abrupt cessation of concentrated glucose may result in profound hypoglycaemia. If parenteral nutrition cannot be continued during transport, 10% or at least isotonic glucose should be substituted and the blood sugar monitored (see below).

(g) *Dialysis*

Respiratory embarrassment may occur during transport if peritoneal dialysis is continued. caval lines in haemodialysis may be conveniently locked off and filled with heparinized saline during transfer. Continuous arterio-venous haemofiltration (CAVH) or haemodiafiltration (CAVHD) may be continued if necessary.

(h) *Counterpulsation*

This may be essential for patients being transferred to cardiac surgery. An arterial pressure display needs to be added to those machines without one. There has to be adequate compressed gas and lead-acid battery endurance for the machine.

(i) *Thermoregulation*

Protection against cold (eg, using a reflecting "space" blanket) and from rain may be required. The hyperthermic patient may require ice packs to be carried, plus specific medications, eg, dantrolene in malignant hyperpyrexia.

(j) *Emergency Pack*

A pack containing laryngoscopy, endotracheal tubes, IV cannules etc enabling mishaps en route to be managed, is essential.

2. Monitoring In Transit

(a) *Clinical Observation* remains pre-eminent. Visual observation and palpation (eg, of chest movement) is necessary when external noise and bright light overwhelm monitor alarms and screens. Documentation of variables remains important, but records necessarily need to be concise.

(b) *ECG* remains a coarse indicator of overall circulatory function. Its prime virtue is detecting catastrophic rhythmic disturbances. Many transport monitors, however, while having an audible QRS "beep" do not have rate alarms. Visual surveillance of the monitor is essential.

(c) *Blood Pressure Measurement*

(i) Non-invasive: clinical auscultation techniques are usually not practical in transit, so palpatory systolic measurement with an aneroid clock is common. Mercury column sphygmomanometers are cumbersome, need vertical positioning and have limited use. There are 3 types of pneumatic cuff BP transducers: piezo crystal microphone (eg, Copal); doppler generator; and the most commonly used, oscillotonometric transducers (eg, Dinamap, PhysioControl). In these, the display is digital, using easily read light-emitting diodes (LED). Most reliable devices are unfortunately considerably heavy.

(ii) Invasive: for indwelling arterial lines, lightweight battery operated display systems are best. A simple non-electronic alternative is to use a heparin filled line connected via a membrane isolator to the air in an aneroid clock. Continuous flushing devices add to the bulk of equipment and intermittent manual flushing may be used instead. Available equipment may not allow pulmonary artery and intracranial pressure to be monitored in transit.

(d) *Respiratory* - A ventilator disconnect alarm should have audible signals above extraneous noise. The small but fragile Wright respirometer remains the most convenient spirometer. There are light pulse oximeters suitable for transport. End tidal CO_2 monitoring is limited in use because of unsuitable models. Transcutaneous oxygen measurement currently is successfully used only in neonates, because of their reduced skin thickness.

(e) *Temperature* - The rectal or oesophageal thermistor probe connected to a digital display is suitable. Glass thermometers are inconvenient and hazardous.

(f) *Biochemical Monitoring* - Potassium and glucose are the principal considerations in short term transport. Reflectance equipment is compact and gives adequate results for glucose. The ECG is observed for changes of potassium abnormality. Biochemical information may need to be more precise in long distance transfer.

Electrical Energy Sources and Safety Considerations

Nickel cadmium rechargeable batteries are commonly used. However, they may fall prematurely because of a "memory" effect. This problem can be reduced by "exercise" (discharge) of the battery to exhaustion at intervals. Sealed lead-acid batteries have been substituted in some situations, because of their greater endurance. However, they are also subject to sudden failure of a different kind. Unlike NiCd batteries they should be kept fully charged and not undergo periodic exhaustion.

If the patient has invasive lines to the heart such as a Swan-Ganz catheter, transvenous pacemaker or central venous line, the risk of microshock arises once removed from the cardiac-protective (class A) or body-protective (class B) electrical isolation environment of the ICU or the operating rooms. Thus battery sources of electrical energy should be used and appropriate precautions taken, such as avoiding contact by staff between patient and a mains powered equipment casing. (See Chapter 75, Electrical Injuries.)

Passage

Hospital doorways, corridors and lifts may not allow movement of a hospital bed fully laden with equipment. Thus trolley transport will often be needed. Care must be taken to avoid injury to the patient and staff when shifting the patient from bed to trolley (or operating table). Coordination of the team, whether using manual, frame, slide or mechanical "crane" methods of lifting/transfer are vital. Particular care is given to patients with spinal injuries. (See chapter 70, Spinal Injuries.)

Extra-Mural Movement

1. Pre-Hospital Transport

Multiple trauma is the common problem requiring hospital based Intensive/Critical Care facilities in this phase. Others include drowning accidents, hypothermia and hyperthermia.

Planning: Acute hospitals, especially trauma centres, should have a radio link with the ambulance services to enable the hospital to prepare for impending arrivals and advise crew members in the field.

Personnel: Experienced medical and nursing staff are appropriate to work with ambulance staff in the field. Junior staff (interns and student nurses) have little place in field activities.

Properties: A complete *mobile intensive care kit* of resuscitation drugs and equipment (Table 1a, 1b) in 3-4 easily portable robust containers (total weight under 40 kg) should be readily available.

Passage: The safety of personnel is paramount. This includes safe transport, protective dress and headgear, identification (eg, "DOCTOR", "NURSE" marked on helmet), and environmental safety (eg, control of fire risks and protection from oncoming traffic).

Procedures: Minimum intervention compatible with expediting safe evacuation is the principle. Examination will be limited, but heavy clothing can conceal major injury. Endotracheal intubation in field conditions may be difficult. Pleural drainage should be effected in the second intercostal space, mid clavicular line, where it can be observed on a transport stretcher. The Heimlich valve is useful, connected to a simple wound drainage bag.

Volume expansion is best achieved with synthetic plasma substitutes in plastic bags (eg, Haemacel). Glass bottles are hazardous. Plastic fluid bags can be easily pressurized by placing under the patient's buttocks. Two or more wide bore IV lines are necessary with extensive blood loss. Group O negative blood may be required for major incidents.

Pneumatic Anti-Shock Garment (PASG) previously called the Military Anti-Shock Trousers (MAST), pneumatically splints the legs and abdomen in major abdominal and lower limb blood loss, to raise peripheral resistance and maintain perfusion pressure to vital organs. They should be used only as a short term measure and not inflated beyond 40 mmHg (5.3

kPa). Circulation to digits should be observed. Deflation should only occur when the patient is ready for immediate surgery as profound hypotension may follow.

Table 1a. *Mobile Intensive Care Equipment for Extra-Mural Transport - Drugs*

Circulatory Drugs
- Inotropes (alpha and beta)
- Alpha and beta blockers
- Atropine (anticholinergic)
- Neostigmine (cholinergic)
- Anti arrhythmics
- Antihypertensives.

Renal Agents
- Diuretics (loop and osmotic)

Allied Drugs
- Potassium
- Magnesium
- Sodium bicarbonate 8.4%
- Calcium chloride
- Glucose, hypertonic

Antibiotics
- Penicillin
- and others as needed

Coagulation Drugs
- Heparin
- Vitamin K1

Uterine Agents
- Oxytocics

Steroids

Respiratory
- Bronchodilators

Nervous System Drugs
- Narcotics
- Narcotic antagonists
- Anticonvulsants
- Sedatives
- Neuromuscular blockers
- Anti-emetics
- Local anaesthetic agents
- General anaesthetic agents (usually IV).

Appropriate intravenous, gaseous or regional analgesic methods are used according to circumstances. Gross angulated fractures with vascular compression should be corrected and splinted. In penetrating injuries, objects which impale the trunk should not be removed until immediate surgery is feasible, as massive haemorrhage may follow immediately.

2. Inter-Hospital Transport

The commonest conditions encountered are neonatal, traumatic and respiratory disorders of such severity that standard ambulance evacuation may not be safe.

Planning: Cooperation and continual communication between the referral and receiving hospitals and the ambulance authority is vital. Treatment advice to the referring doctor pending the arrival of the Intensive Care team may be life-saving.

Personnel: This will vary according to the local situation. Retrieval staff should not be prone to motion sickness, ear/sinus problems, or have difficulty working in confined transport vehicles. An obstetrician and paediatrician should be included in difficult obstetrical/paediatric retrievals. On returning, treatment requirements, eg, need for CT examinations should be relayed ahead.

Table 1b. *Mobile Intensive Care Equipment for Extra-Mural Transport - Equipment*

Respiratory
Airways (Guedel)
Ventilation bag (self-inflating) and masks
Ventilator (compact) and spare exhale valve
Simple spirometer
Intubation equipment:
    endotracheal tubes and adaptors
    introducer
    Magill forceps, artery forceps
    laryngoscopes, blades, globes, batteries
    bronchoscopes, rigid, battery handle type
    suction device, Yankauer handle and supply of catheters
    tracheostomy tubes; Mini-trach (or similar)
Pleural drainage:
    catheters and trocars, wide venous cannulae, scalpel
    Howard-Kelly forceps
    Heimlich valves
    wound drainage bags
Suture material with attached needle
Nebulizer

Circulatory
Monitor / defibrillator
Pulse oximeter
Sphygmomanometer cuff and clock
Electronic BP measurement (invasive/noninvasive)
Venous cannulae (peripheral and central)
IV fluids and pressurization sleeve
Arterial cannulae
Non distensible tubing; bubble isolator or transducer (if equipped for arterial monitoring)
Infusion pump
Giving sets (including those compatible with the pump)
Syringes, needles

Gastrointestinal
Nasogastric tube
Drainage bag

Renal
Urinary catheters and collecting bags

General
Nasal decongestant spray (ear clearance in aircraft)
Torch
Writing equipment, including skin crayon
Medication labels
Patient name labels
Clothing shears
Adhesive tape
Antiseptic (eg, povidone iodine)
Reflecting ("space") blanket.

Procedures: The principle is to stabilize as far as practicable, in the referring hospital before transportation. This includes confirming by X-ray, the position of endotracheal tubes, central lines and drains.

Some emergencies (eg, extradural/subdural haematoma) necessitate the retrieval team to be involved in surgery and anaesthesia prior to evacuation. Difficult obstetrical patients are best evacuated for delivery in a major centre, and are postured accordingly in transit to avoid the supine hypotensive syndrome. Occasionally, emergencies such as haemorrhage or obstructed labour may require rapid operative intervention. Burns patients require volume replacement, oxygenation, analgesia, prevention of hypothermia and coverage of burn areas.

Coverage with silver sulphadiazine is unnecessary and may make the assessment more difficult in the definitive centre. The most common problems in children are respiratory, eg, laryngotracheobronchitis and epiglottitis. Airway control is secured before transport. Potentially violent psychiatric patients are sedated and judiciously restrained before transfer by air.

Properties. Equipment considerations are as previously discussed. Loose equipment should be well secured during transit. The stretcher should be compatible with the aircraft or road vehicle use. It should be noted that mercury instruments and unsealed lead-acid batteries are not permitted in planes. Pulse oximetry will warn of unsuspected hypoxia at altitude, and conversely, end-tidal CO_2 monitors commonly give unreliable data.

Passage: Ideal requirements of any transport vehicle (road or air) are listed in Table 2. Vibration is a common problem in both road vehicles and aircraft. Natural frequencies under 20 Hz of significant amplitude may be deleterious to the patient. Other main physical limitations are altitude effects and dimensions.

Altitude affects -

(a) oxygen partial pressure and

(b) total ambient pressure in dysbaric illness (eg, gas embolism) and air filled cavities (eg, pneumothorax).

While this concerns aeromedical transport, road trips over mountainous terrain can also adversely affect such conditions. The total atmospheric pressure diminishes with altitude. PaO_2 will be reduced proportionately. Even in "pressurized" planes, cabin pressure is equivalent to 2000-2500 m altitude (ie, about 560 mmHg or 75 kPa). It is usually impractical to achieve a better (higher) cabin pressure. Some air ambulances and military transport (eg, Hercules) may achieve sea level pressure. This is at the cost of a lower, less efficient altitude and a possibly bumpier trip. Fortunately, most patients travel well at conventional cabin pressures. Precautions are thus undertaken to overcome the lower ambient pressure at altitude.

Table 2. *Ideal Requirements for A Transport Modality*

Physically safe.
No abrupt movements in any axis.
Sufficient room for at least one critically ill patient, with an attendant at the head end.
Adequate supply of energy and gases for life support systems.
Easy embarkation and disembarkation of patient.
Adequate lighting and internal climate control, including cabin pressurization.
Tolerable noise and vibration levels.
Adequate traveling speed.
Minimal secondary transport (eg, road transport in air evacuation).
Good communication systems.

(a) *Oxygen Supplementation:* is especially necessary if it has been required at sea level.

(b) *Intravenous Lines:* the higher pressured air enclosed in a drip chamber will cause a faster drip rate or retrograde flow up into the bag. The reverse will be seen on descent.

(c) *Endotracheal Tube Cuff:* will expand at altitude. If cuff pressure becomes excessive, cuff volume should be adjusted. The reverse change on descent may cause a cuff-seal leak, though it is not a common problem. Cuff inflation with water is not commonly practised.

(d) *Air in Enclosed Body Cavities:* an enclosed, compliant cyst may be calculated to increase its radius by 15% and its volume by 50% at 3000 m, where ambient pressure is approximately 500 mmHg (66.5 kPa). This effect of air-space expansion at altitude is reduced by denitrogenation, ie, washing out nitrogen, the principal gas of air, by breathing 100% oxygen before and during flight. Such attention is hence given to patients with, eg, gut distension, blocked sinuses, and intracranial air.

(e) *Penetrating Eye Injuries:* loss of vitreous and other contents can occur if intra-ocular pressure is raised above the ambient, eg, with vomiting, coughing, straining or hypoxia. Entrapped air may produce discharge of globe contents at altitude. These effects may be minimized by eye binding, antiemetics, sitting up the patient and breathing 100% oxygen.

Nitrous oxide analgesia should not be used in patients with decompressed sickness, as a counter-diffusion effect may enhance bubble size. Its prolonged use in patients with entrapped gas may similarly be hazardous. The inflation pressure of PASG suits increases at altitude. Worsening of regional compression should be watched for, and corrected if necessary. Plaster of Pairs encased limbs may swell during long distance aeromedical transport. It is prudent to carry plaster shears on such trips.

Transport Vehicles

(a) *Road Vehicles:* are the common mode for metropolitan and shorter trips under 150 km. Vehicular design should allow adequate room for patient care and the other requisites (Table 2). In elective transfers, speed is not a requirement, and drives should be thus informed.

(b) *Fixed Wing Aircraft:* The requisite qualities are outlined (Table 2). Fortunately, many such aircrafts are pressurized and the appropriate cabin pressure should be discussed with the pilot before departure. Intermediary road transport is inevitable, and adds to the total transit. Extra staff for the vital shift to and from the aircraft may be needed. There is little difference in positioning the patient head or feet first in the plane. Transverse positioning produces the least inertial change in body fluids but is usually not possible.

(c) *Rotocraft:* The advantage of the helicopter is mobility, enabling landing near an incident. This is lost if significant secondary road transport from helipad to destination is required. Their altitude is usually less than in fixed wing operations. The internal dimensions of commonly used civilian craft at the present time (Squirrel, Bell Long Ranger, BO-105) are less than those of fixed wing ambulance craft, and so prior stabilization of a patient for transport is especially necessary. Nevertheless, even a small craft may serve as emergency outbound transport of a medical team, who may return with their patient by other means.

3. International or Long Distance Transport

Planning: It is generally better to await major resolution of a disease or injury before evacuation. Good liaison between the foreign country's physicians and the retrieval team is necessary. The team should take over management formally at the foreign hospital and not at an airport. A secretariat is necessary to co-ordinate the complex arrangements before the flight. This includes the amount of equipment to be taken, availability of supplies en route, road transport, legal rights of the team on foreign soil including carriage of narcotics. Sufficient staff numbers are taken to enable conventional (8-12 hour) shifts to be worked.

Passage: The patient may be evacuated by a private aeromedical transport organization, military aircraft, chartered executive-style aircraft, or most commonly, commercial jet aircraft. One continuous route should be planned if possible. Up to 15 seats are needed with a complex case: 6-8 for the stretcher, 2 for equipment, 2 for medical gases (secured according to regulations), plus a seat for each of the team (up to 5).

Properties: Equipment considerations are similar to those discussed. A duplicate ventilator is essential in extended trips. Ability to use room air is desirable, to cope with a possible oxygen supply difficulty. Gas (oxygen) supplies need to be sufficient for twice the anticipated duration to cover unscheduled ground stops. Bridging junctions should be carried as foreign countries may have incompatible oxygen connections. Routine biochemical monitoring may become a priority in prolonged transport. Dry chemistry equipment and ion specific electrodes (eg, CHEMPRO 500, KODAK DT60) are useful. Commercial airlines commonly have 28v DC. However, during stopovers, aircraft electrical power may be shut down. Waste disposal of syringes, needles, excreta, etc, need to be considered.

Other Special Types of Transport

1. Neonatal

Specialized neonatal retrieval teams with life-support incubators are able to move sick neonates over long distances.

2. Hyperbaric Transport

The effect of altitude on dysbaric conditions may be countered with hyperbaric oxygen (HBO) using a transportable recompression chamber. On arrival, it is possible to transfer such patients under pressure to a large multiplace hyperbaric Intensive Care chamber without the need to interrupt HBO. Carbon monoxide intoxication victims may be similarly treated.

3. Movement of ICU Patients in a Fire Threat

The greatest cause of death in building fires is smoke inhalation, and poisoning by carbon monoxide and cyanide. Consequently, staff should first move the spontaneously breathing patients, leaving ventilated patients till last, by which time smoke infiltration may have subsided. Lifts should not be used in a fire.

4. Movement in a Disaster

A disaster may be defined medically as one which overwhelms the regional medical resources. It is not the total number so much as the rate of delivery of seriously ill patients from the site to hospital which overwhelms facilities. Acute hospitals must be prepared to mobilize a medical team as part of its response to a disaster. Because of the numbers of patients, counter disaster medicine is more basic. Hence equipment taken and procedures done are designed to do the greatest good for the greatest number.

On site medical teams have two distinct roles: triage, then treatment prior to transport. Triage (prioritisation) has similarities to the selection of patients for Intensive Care, though on a grander scale. Triage requires an experienced clinician to work with ambulance authorities to divide patients into such categories as:

(a) non or mildly injured;

(b) moderately injured to be evacuated by ambulance crews;

(c) severely injured and/or trapped;

(d) dead or mortally injured (eg, severe compound brain wound) to be left aside until later.

Treatment should proceed after triage so that resources can be best utilized. Group (c) which cannot be moved quickly, will benefit from on-site attention of medical teams, who should not duplicate the work of ambulance staff. These patients require measures such as IV therapy, narcotics, pleural drainage, and if necessary, surgery and anaesthesia for extrication or amputation of mangled, trapped limbs. In most situations, this group comprises a small percentage of the total.

Chapter 4: Physiotherapy in the ICU

W Jacob

Techniques of chest physiotherapy have been documented since 1901 for the treatment of a wide range of pulmonary disorders. Despite a large volume of research in the last 25 years, controversy persists on the optimal modalities to be employed. This is primarily due to inappropriate application of chest physiotherapy or variations in research design; for example, in the failure to

1. standardize nomenclature, patients studied and objective measures, and to

2. distinguish acute from chronic pathology and prophylactic from therapeutic treatment.

Physiotherapy nevertheless remains an important aspect of the overall management of an Intensive Care patient. A properly established Intensive Care Unit should provide for experienced physiotherapists on a 24 hour basis.

Rationale for Chest Physiotherapy

Following the institution of mechanical ventilation via an endotracheal tube or tracheostomy, pathophysiological changes occur in lung function that predispose the patient to pulmonary complications. Pulmonary insults and diseases magnify these pathophysiological changes. Some of these factors are outlined below:

1. Decreased mucocilliary clearance

The presence of an artificial airway increases mucus production and decreases ciliary activity. Inadequate humidification further impairs this mechanism.

2. Colonization of the lower respiratory tract with upper respiratory tract organisms

Contamination of the lower respiratory tract occurs during intubation and with intermittent cuff leaks. The number of organisms in the oropharynx is increased as hygiene is difficult in intubated patients. Infection is likely to occur in compromised patients, eg, debilitated patients, in the presence of hypoxia, acidosis, uraemia or prolonged hospitalization.

3. Ventilation-perfusion (V/Q) mismatch

Ventilation is preferentially distributed to nondependent lung regions in the paralyzed, mechanically ventilated patient. The mechanisms involved are thought to be loss of lung volume in the dependent lung resulting in a decrease in compliance, and the passive movement of the diaphragm. Normally diaphragmatic movement is greatest in the domed portion (due to the stretch on its fibres). As this mechanical advantage is lost in the paralyzed, ventilated patient, the greatest diaphragmatic displacement is in the nondependent lung regions. Perfusion, however, remains greatest in dependent regions.

4. Increase in deadspace ventilation

If alveolar pressure is increased and/or pulmonary artery pressure is decreased, deadspace ventilation is increased. A decrease in alveolar perfusion occurs in nondependent lung regions due to a decrease in pulmonary artery pressure and the effect can be magnified with the application of positive end-expiratory (PEEP) especially in non-diseased lung units.

5. Uneven distribution of ventilation

Distribution of ventilation is altered by disease. Ventilation of a lung unit is determined by its local distensibility and airway resistance. A decrease in lung or chest wall compliance and an increase in airway resistance results in the closure of small airways at higher lung volumes and an increase in the closing volume. Failure of the airway to reopen leads to collapse of the lung unit and hypoxaemia. Ventilation is preferentially distributed away from those lung units that have a decrease in compliance and/or an increase in airway resistance. Other factors that promote alveolar collapse include the supine position, pain, use of sedatives/narcotics and immobility.

Techniques

Physiotherapeutic techniques are designed to minimize the effects of any disease state and promote normal function.

Physiotherapists are involved directly with the prevention of pulmonary complications. Changes in the status of other systems (cardiovascular, neurological, musculoskeletal, haematological, renal or nutritional) can influence techniques performed and expected outcomes.

The aim of physiotherapy are to:

1. Improve V/Q relationships, thereby decreasing the risk of alveolar collapse and pulmonary infection.

2. Maintain joint and soft tissue range.

3. Encourage active movements, thereby diminishing the risk of deep vein thrombosis, and promoting normal musculoskeletal and neurological function.

4. Encourage mobilization to minimize the detrimental effects of bed rest.

5. Initiate rehabilitation programmes focusing on major problems.

Positioning and Postural Drainage

Correct positioning should be an integral part of the management of the critically ill patient.

The influence of posture on the distribution of ventilation in awake, spontaneously breathing patients and sedated, mechanically ventilated patients has been studied, suggesting that the variation in pleural pressure gradient is not only dependent on posture, but also on selective contraction of inspiratory muscles. Therefore, in patients who are mechanically ventilated but not paralyzed, the distribution of ventilation can be altered by active contraction of the inspiratory muscles and depends on the difference in mechanical properties of the two hemithoraces.

Increasing lung volume from functional residual capacity (FRC) by either manual bagging or controlled breathing exercises, enhances V/Q matching by decreasing airway resistance, improving collateral flow and mobilizing secretions.

Unless a specific lung segment is to be drained, positions that increase FRC are indicated. Sitting with the hips flexed (not "slumped") and accurate side-lying allow the diaphragm greater mobility while the supine position should be avoided as it decreases FRC. Postural drainage positions should only be used for gravity-assisted drainage of specific lung segments. Certain conditions require special consideration when positioning the patient, especially prior to tipping (Table 1).

Table 1. *Conditions Requiring Special Consideration When Positioning*

1. Sever hypertension.
2. Acute myocardial infarction/cardiac arrhythmias.
3. Congestive cardiac failure/pulmonary oedema.
4. Raised intracranial pressure (eg, head injury, cerebrovascular accident, cerebral oedema).
5. Cerebral or aortic aneurysms.
6. Dyspnoea.
7. Oesophageal operations/hiatus hernia/regurgitation.
8. Eye surgery.
9. Peritoneal dialysis/haemodialysis/haemofiltration.
10. Ascites.
11. Abdominal distension.
12. Pneumonectomy.

Percussion and Vibration

Percussion and vibration are manual techniques that can be used in conjunction with posturing, postural drainage, manual bagging and controlled breathing exercises to assist the mobilization of secretions from peripheral to central airways. Certain condition that may require modification of the percussion technique (Table 2).

Table 2. *Conditions Requiring Modification of Percussion*

1. Fractured ribs, vertebrae or sternum.
2. Pleuritic or other chest wall pain, eg, carcinoma of the lung, secondary rib carcinoma, lung abscesses, pulmonary embolus.
3. Acute myocardial infarction and arrhythmias.
4. Haemoptysis.
5. Coagulopathies, thrombocytopenia, disseminated intravascular coagulation.
6. Osteoporosis.
7. Osteomyelitis of the rib cage.
8. Bronchospasm.
9. Incisions/burns/grafts.
10. Severe surgical emphysema.

Manual Bagging

Manual bagging can be used as an adjunct to other physiotherapy techniques to improve lung expansion. Various resuscitation or anaesthetic bags are available but only those bags capable of delivering 100% oxygen should be used. (See Chapter 6, Cardiopulmonary Resuscitation.) Bagging is used to:

1. Hyperoxygenate pre and post suctioning.
2. Improve V/Q matching by increasing lung volumes, increasing compliance and decreasing airway resistance.

Bagging is an effective, safe technique provided the operator continually adjusts the rate, tidal volume and pressure, in response to changes in the patient's lung compliance or airway resistance. The "bag-squeezing" technique using a four-to-five litre anaesthetic bag is generally not used due to complications of barotrauma and significant decreases in venous return. The potential complications of bagging include:-

1. Barotrauma due to high airway pressure.

2. Hypotension and decrease in cardiac output.

3. Raised intracranial pressure (ICP).

4. Hypoventilation due to poor technique or patient "fighting" the bagging.

5. Hyperventilation and loss of respiratory drive due to a fast rate.

The following guidelines promote a correct technique:

1. Select flow rate to achieve required fractional inspired oxygen (FIO_2).

2. Check operation of bag prior to connection to the patient.

3. Hyperventilate following connection.

4. Determine rate according to patient's respiratory effort. If the patient has no respiratory drive, bag at similar rate to ventilator rate unless otherwise indicated. If the patient does have a respiratory drive, synchronize manual breaths with patient's breaths

5. Consider bag volume, patient's size and airway pressure when determining volume.

6. Hyperventilate prior to suction and reconnection to ventilator.

Suctioning

Suctioning is required to stimulate the cough reflex and remove secretions in patients who are unable to cough or have an ineffective cough (despite other physiotherapeutic techniques, eg, forced expiratory techniques, huffing, tracheal rub and optimal positioning).

Suctioning is, however, a potentially dangerous technique. Complications of suctioning are:

1. Tracheobronchial trauma including mucosal haemorrhage, oedema, ulceration and destruction of ciliated epithelium.

2. Bronchial obstruction as damaged ciliated epithelium is repaired by squamous metaplasia and fibrous tissue.

3. Hypoxia. Definitive mechanisms are unknown but suggestions include suction-induced atelectasis or reflex bronchoconstriction caused by mechanical stimulation of the trachea.

4. Cardiac arrhythmias. Atrial and nodal arrhythmias are the most common and occur if the patient is breathing air while suctioned. Pre-oxygenation with 100% oxygen abolishes these arrhythmias. Vagal stimulation, however, can occur and may result in significant bradycardia or even cardiac and respiratory arrest.

In non-intubated patients who require suction via a nasotracheal or orotracheal route the risk of complications is high. Other precautions or contra-indications to suction in non-intubated patients are shown in Table 3. The following guidelines, therefore have been recommended:

1. Suction to be performed when indicated and not on a routine basis to decrease the risk of tracheobronchial trauma.

2. Hyperoxygenate to decrease the risk of hypoxia and cardiac arrhythmias.

3. Limit the suctioning time to fifteen seconds to decrease the risk of hypoxia.

4. Observe the patient's vital signs (including colour, distress, heart rate, respiratory rate, blood pressure and oxygen saturation) pre, during and post suction and discontinue treatment if any adverse effects occur.

Minitracheotomy should be considered for patients who require frequent orotracheal or nasotracheal suction and are at risk of developing respiratory failure due to sputum retention. (See Chapter 21, Endotracheal Intubation and Tracheostomy.)

Table 3. *Precautions/Contraindications to Suctioning*

1. Cerebrospinal fluid leaks.
2. Fractures involving the nose, face, base of skull.
3. Epistaxis, deviated septum, general facial trauma.
4. Coagulopathies.
5. Hyper-reflexic gag reflex.
6. Mouth and neck surgery.
7. Laryngospasm, glottic oedema.
8. Tracheitis, bronchospasm.

Patient Mobilization

Early mobilization is essential if the detrimental effects of bed rest are to be minimized. It may also decrease the rehabilitation time.

Positioning, passive and active movements and resistive exercises are routinely performed by physiotherapists. Mobilization also includes sitting the patient out of bed when vital signs are stable. Standing and ambulation with appropriate assistance and aids should be encouraged as this also decreases the need for frequent and vigorous chest physiotherapy. The tilt table may be used in the early rehabilitation of patients with:

1. General debilitation due to prolonged bed rest.

2. Cardiovascular instability.

3. Neurological dysfunction.

4. Musculoskeletal disorders.

Adjuncts to Chest Physiotherapy

1. Intermittent Positive Pressure Breathing (IPPB)

Despite early enthusiastic descriptions of the beneficial effects of IPPB in the treatment of acute asthma, chronic obstructive airways disease (COAD), pneumonia and prevention of post-operative pulmonary complications, the use of IPPB is now controversial. There is little clinical evidence to support its necessity, efficacy and cost-effectiveness over other forms of respiratory therapy. Complications are reported in the literature (Table 4).

Table 4. *Complications of Intermittent Positive Pressure Breathing*

1. Increased work of breathing.
2. Air trapping.
3. Risk of pneumothorax.
4. Carbon dioxide narcosis.
5. Depressed cardiac output.
6. Cross-infection.
7. Gastric distension.

2. Incentive Spirometry

Early studies found incentive spirometry to be more efficacious than IPPB or routine chest physiotherapy. Recent studies have failed to demonstrate that incentive spirometry offers significant advantages over other forms of respiratory therapy in the prevention of post-operative complications.

3. Periodic Continuous Positive Airway Pressure (CPAP) by Mask

The application of periodic CPAP by mask in the post-operative patient has been demonstrated to be more effective than IPPB, incentive spirometry, or deep breathing and coughing exercises alone. A more rapid increase in FRC occurs in patients who receive CPAP. The application of CPAP by mask for the treatment of respiratory failure secondary to low lung volumes is an area that requires further investigation. Potential complications of CPAP are:

1. Decrease in cardiac output; however, spontaneous ventilation decreases the incidence and severity of this complication.

2. Vomiting and aspiration of gastric contents; this is minimized if CPAP is used in awake, cooperative patients and by the insertion of a nasogastric tube to reduce gastric distension.

3. Carbon dioxide retention.

4. Skin erosion; minimized by the use of soft, easily molded silicone elastomer masks.

One single method of treatment, however, is unlikely to prevent post-operative complications. Any manoeuvre that encourages the patient to perform sustained maximal inspiration is likely to decrease the incidence of pulmonary complications. The costs involved in supplying these aids needs to be considered when discussing the effectiveness of these modalities.

Adverse Effects of Chest Physiotherapy

The problems of chest physiotherapy and their contributing factors and recommended treatment are shown in Table 5.

Frequency of Treatment

Ideally, physiotherapy is continued throughout a 24 hour period. The frequency of treatment is individualized for each patient and may vary from two hourly to four/six hourly. It is determined by assessment and response to treatment.

1. Assessment

(a) *Rationale for instituting mechanical ventilatory support.* The major indication for mechanical ventilation is acute respiratory failure. Other indications include:

(i) elective ventilation for high risk post-operative patients.

(ii) hyperventilation ($PaCO_2$ 25-30 mmHg (3.3-4.0 kPa)) to help control ICP and to prevent adverse sequelae of neurological and neurosurgical events.

(b) *Influence of other systems* including signs of sepsis, cardiovascular or neurologic dysfunction, metabolic and electrolyte disturbances, haematological disorders.

(c) *Respiratory function.* Evaluation of the following parameters is required:

(i) mode of ventilation and FIO_2;

(ii) respiratory mechanics (tidal volume or minute volume, respiratory rate, airway pressure);

(iii) arterial blood gases;

(iv) auscultatory signs;

(v) chest X-ray findings.

2. Response to Treatment

Selection of treatment techniques has been discussed in previous sections. All patient parameters require ongoing evaluation to promote safe and effective treatments. Routine treatment programmes are not only ineffectual but also potentially dangerous as important clinical signs may be missed.

Special Considerations

To effectively prevent secondary pulmonary complications it may be necessary to increase the frequency of treatment in the following circumstances:

1. Paralyzed Patient

Patients who are paralyzed and sedated and therefore in a controlled mode of ventilation, have an increased risk of developing progressive atelectasis due to physiological changes described earlier. Major collapse and consolidation is also a significant possibility due to the loss of the cough reflex.

2. Positional Restriction

If correct positioning is not possible (eg, spinal fractures, elevated ICP, and skeletal traction) collapse/consolidation may occur in pulmonary segments which cannot effectively be treated.

3. Length of Treatment

Certain disease states (eg, severe hypoxaemia, cardiac arrhythmias, and elevated ICP) necessitate treatments to be kept brief and therefore an increase in frequency may be required.

4. Pre-existing Pulmonary Disorder (eg, COPD)

Immobility and artificial ventilation frequently aggravate the pathophysiological changes which occur with pulmonary disorders.

5. Poor Airway Control and Ineffective Cough

If the patient is unable to adequately maintain an airway or clear secretions effectively (eg, bulbar palsies, and postoperative patients) an increase in the frequency of treatment may prevent respiratory failure.

6. Abnormal Breathing Patterns

With spontaneous modes of ventilation (eg, Intermittent Mandatory Ventilation, Pressure Support, CPAP, and T-piece) paradoxical or shallow, rapid breathing patterns can occur thereby increasing the risk of collapse or consolidation.

7. Decreased Level of Consciousness

If the level of consciousness is decreased, whether it is due to artificial agents (eg, paralyzing agents, sedatives, or narcotics), neurological dysfunction or metabolic disturbances, pulmonary dysfunction can result.

If the patient is able to co-operate with physiotherapy, positioning and mobilization, then it may be possible to decrease the frequency of treatment. This would also contribute to the minimization of the detrimental effects of sleep deprivation.

Table 5. *Adverse Effects From Chest Physiotherapy*

Problem	*Contributing Factors*	*Remedial Action*
Decreased PaO_2	Low PaO_2 High FIO_2 PEEP > 15 cmH_2O (1.5 kPa)	Treat with 100% O_2 Do not disconnect from ventilator. Use swivel connectors with a self-sealing diaphragm to minimize the decrease in PEEP during suction. Short treatment sessions.
Increased ICP	Non-paralysed patient ICP > 15 mmHg (2.0 kPa) Suction decreasing venous return Increased $PaCO_2$ during manual bagging	IV bolus of sedative, narcotic or paralysing agents. Capnometer incorporated into circuit to monitor. $P_{ET}\ CO_2$. Short treatment sessions. Minimize other stimuli prior to treatment.
Hypertension & tachycardia	Pain, anxiety	IV bolus of sedative, narcotic.
Hypotension	Hypovolaemia Decreased CO Air trapping in patient with severe COAD	Correct bagging technique. Decrease rate to allow maximal expiratory time.

PaO_2 : Partial pressure of arterial oxygen.
$PaCO_2$: Partial pressure of arterial carbon dioxide.
$P_{ET}\ CO_2$: Partial pressure of end tidal carbon dioxide.
CO : Cardiac output.