Hospital Topics

An economical mobile intensive care unit

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Summary and conclusions

A mobile intensive care unit is an important extension of a regional intensive treatment service. The treatment and monitoring of critically ill patients can be maintained during transfer for specialist investigation or treatment. Such units can be brought into service with low construction and running costs.

Introduction

The condition of critically ill patients is likely to deteriorate if they are moved, whether between hospitals or within the same hospital.¹ Such patients may benefit ultimately from being moved either from a general ward or a peripheral hospital to an adequately equipped and staffed intensive therapy unit or from an intensive therapy unit to a specialist investigative unit—for instance, for computed tomography or ultrasound scanning. Many clinicians, however, are concerned about the risks of the journey itself. Either they may refuse to move the patient and thus deny him specialist investigation or treatment or they may disconnect the patient temporarily from cardiovascular monitoring apparatus and from controlled respiratory and cardiovascular support and rush him to his destination to minimise the time "at risk."

To overcome this problem a mobile intensive care unit incorporating complete, independently powered intensive care facilities was developed in Glasgow²⁻⁴ and was shown to provide a means of moving critically ill patients safely, either between or within hospitals.⁵ As a custom-modified ambulance was purchased,* however, the Glasgow mobile intensive care unit was relatively expensive to develop; and it is staffed by three doctors whose clinical work load is related to its use.

In Oxfordshire many patients need transport to the intensive therapy unit in Oxford, either from other hospitals in the city or from hospitals in other towns in the region. In addition, since the opening of the John Radcliffe Hospital in July 1979, critically ill patients have had to be transported to the neurosurgical unit at the Radcliffe Infirmary, nearly five kilometres distant, either for computed tomography or for neurosurgical operative procedures, and neurosurgical patients who have developed severe pulmonary or other extracranial complications

have had to be moved to the intensive therapy unit at the John Radcliffe Hospital. We describe here the mobile intensive care unit that has been developed to carry such patients safely.

Trolley

A hospital trolley has been modified to form the main part of the mobile intensive care unit (fig 1). At its head is a gas supply system, with two size E oxygen cylinders mounted obliquely, two size D nitrous oxide cylinders mounted vertically, reducing valves, a rotameter block, and an oxygen failure alarm and safety interlock device (Gardner) to prevent the delivery of a hypoxic mixture of gases in the event of oxygen pressure failure. Flexible hoses with Schrader

FIG 1—MICU trolley. See text for details of equipment.

probes enable gas supplies to be obtained from pipeline systems in the ward or theatre before moving the patient or in the ambulance during the journey. An injector suction device (Medishield) is fitted. All gas and suction controls are protected by a crash bar. The gas is normally conducted to the ventilator, mounted on a shelf beneath the patient. A Manley Pulmovent MPP (Medishield) ventilator was selected because, being a gas-driven minute volume divider, it is economic in its use of gases, requires no electrical power source, and has no external moving parts. Positive end-expiratory pressure can be applied easily, and double-length inspiratory and expiratory tubing is fitted so that the ventilator can be used while the patient is being stabilised in his hospital bed before the journey.

A cardiovascular monitor (Statscope II; Becton-Dickinson) is mounted above the patient's feet. The oscilloscope displays electrocardiograph and intra-arterial pressure or finger plethysmograph traces, with a digital display of heart rate; systolic, mean, and diastolic arterial pressures; and temperature.

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An Imed 922 volumetric infusion pump, which is clamped to a drip pole, enables precise volumes of fluid or pharmacological agents to be infused at a preset rate, independent of the height of the infusion bottle.

A synchronised defibrillator (Cambridge Medical Instruments Ltd, model 73618) is on a shelf beneath the patient's feet. The monitor, infusion pump, and defibrillator each incorporate a rechargeable nickel cadmium battery pack. Beside the defibrillator is a small rigid case containing a wide range of drugs and disposable equipment.

The patient lies on an air mattress for protection from transmitted vibration, and heat loss is minimised by covering him with an aluminised blanket.

Ambulance

For journeys between hospitals the trolley is carried in a modified ambulance. The vehicle is a four-year-old Bedford Ibis ambulance that was scheduled for replacement. It is fitted with soft suspension, which is ideal for providing the smooth movement needed by critically ill patients, and has automatic transmission, which results in smooth acceleration. The rear compartment (fig 2) has been adapted to accommodate the trolley: recesses have been fitted in the floor to secure the trolley wheels, and sockets hold ratchet clamps that lock the trolley in place; two size F oxygen cylinders and one size F nitrous oxide cylinder are connected through reducing valves to pipeline systems supplying Schrader sockets, into which probes from the trolley can be plugged.

FIG 2—Trolley loaded and locked in position in rear compartment of ambulance. Note large range of equipment stored in cupboards.

FIG 3—Trolley and ambulance, with loading ramps in position.

The rear compartment of the Ibis is large (3.1 m × 1.9 m) and has allowed the trolley to be sited in the middle with all-round access by the attendant staff. We consider it important to have access to both sides of a patient, who may have multiple infusion and cannulation sites, bilateral pleural drains, etc.

The rear compartment of the vehicle incorporates fluorescent lighting and a large movable floodlight. An extractor fan helps clear pollutant gases.

The trolley is loaded and unloaded with the help of aluminium ramps (fig 3). These are stored during transit on the floor beneath the trolley but are attached easily to the rear of the floor when required.

Six storage cupboards at the rear of the vehicle carry a wide range of disposable and non-disposable items of equipment that might be required during the journey.

Staffing

Requests to use the mobile intensive care unit are first made to the nursing staff in the intensive therapy unit. The consultant or senior registrar on call for the intensive therapy unit is informed, and he contacts the referring clinician to discuss the request. If use of the mobile intensive care unit is appropriate the ambulance controller instructs the nearest available ambulance crew to collect the vehicle from ambulance headquarters and to drive the two and a half kilometres to the John Radcliffe Hospital to collect the trolley, together with a member of the intensive therapy unit medical staff and an intensive therapy unit nurse. The mobile intensive care unit then travels to the referring hospital. This call-out procedure inevitably takes several minutes, but since the patient is already receiving medical attention, speed should seldom be of paramount importance.

Discussion

The efficacy of a mobile intensive care unit in safely transporting the critically ill patient has been established by the Glasgow Shock Study Group,²⁻⁵ which emphasises the importance of three factors when the movement of such patients is contemplated: a degree of cardiovascular and respiratory stability before they are moved, adequate sedation and analgesia during the journey, and a smooth ride. Waddell¹ found a high incidence of serious cardiovascular complications in critically ill patients moved by conventional means inside a hospital, which underlines the importance of continuous intensive treatment during all parts of a journey, either within or between hospitals. Without the equipment that a mobile intensive care unit incorporates, artificial ventilation and pharmacological cardiovascular support cannot be controlled accurately, and cardiovascular function cannot be monitored satisfactorily. Thus there is inevitably a temptation to complete the journey in the minimum possible time, which almost invariably results in rough movement.

The Oxford mobile intensive care unit is modelled on the original unit in Glasgow, although modifications have been made to construct and staff it more economically, and several improvements have been incorporated.

Because the Oxford mobile intensive care unit will carry a considerable number of patients with intracranial lesions, the trolley will go either head first or feet first into the ambulance. An acceleration force towards the head of a seriously ill patient tends to cause fewer pronounced cardiovascular problems than an acceleration force towards the feet.⁶ In British ambulances, which are relatively underpowered, acceleration forces tend to be less severe than deceleration forces produced by braking, and critically ill patients travel more safely head first. Patients with raised intracranial pressure, however, may suffer further increases in pressure in response to an acceleration force towards the head. We have yet to determine whether in practice such patients will benefit more from travelling feet first.

Vibrations during travel can cause cardiovascular complications,^{6, 7} but in the design of a patient-suspension system for a unit such as this a compromise must be found between absorp-

tion of vibrations and some rigidity to support the vertebral column should external cardiac compression be necessary. A soft spring mattress (or springs in the trolley axles) makes efficient closed chest cardiac massage difficult. An air mattress effectively prevents transmission of vibration from the trolley to the patient and damps inertial movement. If cardiac massage is necessary the mattress can be deflated within 10 seconds.

Although a hydraulic loading lift on the tail of the ambulance would allow the trolley to be maintained in a horizontal position, such devices are very expensive to fit, and we thought that tilting patients for the few seconds needed to load or unload the trolley would be unlikely to cause anything more than a transient alteration in cardiovascular function.

Using surplus or renovated items of equipment where possible has minimised the capital cost of the mobile intensive care unit. The ventilator, defibrillator, and monitor were purchased specifically for the mobile intensive care unit, as were some parts of the gas-supply system. Engineers in the Nuffield department of anaesthetics modified the trolley, and the ambulance service undertook the alterations and refurbishing of the ambulance. The trolley and its equipment are maintained by technicians of the Nuffield department of anaesthetics, and the ambulance by ambulance service engineers.

As the mobile intensive care unit is manned by those members of the ambulance, medical, and nursing staff who are on call running costs should be low. A senior member of intensive therapy unit medical staff is readily available at all times, and can usually leave the unit temporarily to undertake a transfer. On rare occasions when this is not possible a senior member of the on-call anaesthetic team accompanies the mobile unit. An

ambulance crew is required to move the patient whether the mobile intensive care unit is used or not, though the total period of the journey may be longer when it is used. If there is to be a considerable delay before the patient is fit to travel the ambulance crew can resume their normal duties and be called back when required.

We believe that a mobile intensive care unit can make an important contribution towards the safe movement of critically ill patients and that it is a logical extension of a regional intensive care service. With co-operation between clinical, technical, and ambulance staff, such units can be brought into service with low construction and running costs.

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Lesson of the Week

Acute congestive cardiac failure in a hypertensive woman receiving salbutamol for premature labour

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Beta-sympathomimetic agents, such as salbutamol, are widely used to manage premature labour. Pulmonary oedema due to left-sided heart failure has been reported in patients receiving both beta-sympathomimetics and corticosteroids.¹ Cardiac failure developed in a patient of ours when salbutamol was prescribed in combination with an antihypertensive drug.

Case report

A 28-year-old previously normotensive West Indian primigravida woman had no clinical evidence of pre-existing cardiac disease. At 27 weeks' gestation her blood pressure rose to 170/100 mm Hg. During the next four weeks diastolic pressure was main-

Antihypertensive treatment combined with a beta-sympathomimetic drug given to delay premature labour may cause congestive cardiac failure.

tained below 100 mm Hg with alpha-methyldopa, the daily requirement increasing from 1.5 to 2.5 g. Premature labour began at 32 weeks' gestation, and her blood pressure rose to 210/140 mm Hg. Salbutamol, 6 µg/min, was infused to suppress uterine activity. Hydrallazine was started with a 10-mg bolus and an infusion was maintained at 27 µg/min for three hours. Six hours after starting salbutamol the patient became breathless with tachypnoea (30 respirations/min). Central venous pressure rose to 8 cm H₂O, and a third heart sound was heard. An electrocardiogram (ECG) showed sinus tachycardia of 130 beats/min. The patient became anuric: the plasma concentration of potassium was 3.2 mmol/l (mEq/l) (normal range 3.7-5.0 mmol/l) and of bicarbonate 11 mmol/l (mEq/l) (normal range 24-34 mmol/l). The tachypnoea, central venous pressure, and plasma bio-

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