STUDIES ON THE EFFECTS OF MOVEMENT ON CRITICALLY ILL PATIENTS

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CONTENTS

ILLUSTRATIONS

LIST OF TABLES

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DECLARATION OF COLLABORATION AND PREVIOUS PUBLICATION

Dr. I. McA. Ledingham initially suggested taking advantage of the redevelopment of the Western Infirmary on two separate sites to study the transfer of critically ill patients. Background research and detailed planning of all studies was done entirely by myself, with the exception of the second phase of the ITU flying squad (Study IIc) where the electronic recording equipment was developed and provided by Dr. H. Green of the Division of Bio-engineering, Clinical Research Centre, Watford Road, Harrow, and planning was a collaborative effort with Dr. I. McA. Ledingham and other members of the shock team.

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Previous publication and presentation of most of the material in this thesis is listed below:

	Corresponding part of thesis
Waddell, G. (1975) Mountain rescue transport. Injury, 6, 306.	Ia
Carty, M. & Waddell, G. (1975) Ambulance transport of obstetric emergencies. Scottish Medical Journal. In press.	Ib
Waddell, G. (1973) Cardiovascular and other effects of transport on critically ill patients. Presented to the First International Symposium on Mobile Intensive Care Units, Mainz, Germany.	I
Waddell, G. (1973) Patient care during inter-hospital transfer. Presented to the First International Symposium on Mobile Intensive Care Units, Mainz, Germany.	Ic, IIb
Waddell, G. (1974) Ambulance transport of critically ill patients. Presented to the Scottish Orthopaedic Club.	Ic, IIab
Waddell, G., Scott, P.D.R., Lees, N.W., Ledingham, I. McA., (1975) Effects of ambulance transport on critically ill patients. British Medical Journal, 1, 386.	Ic, IIab
Waddell, G., Stuart, B.S., Tehrani, M.A., McGarrity, G., Reyes, A., Smith, H.C., Ledingham, I. McA., Green, H.L., Weller, C. (1975) Intra-arterial monitoring of critically ill patients in ambulances. British Medical Journal. In press.	IIc
McGarrity, G. & Waddell, G. (1975) Effect of transport on the critically ill. Presented to the Scottish Orthopaedic Club.	IIc
Tehrani, M.A. & Waddell, G. (1975) The intensive care unit and ambulance transfer. Presented to the West of Scotland Surgical Association.	IIcd

Stuart, B., McGarrity, G., Tehrani, M.A., Reyes, A., Smith, H., Waddell, G., Ledingham, I., McA. (1975) Effect of ambulance transfer on cardio-respiratory measurements in critically ill patients. Presented to the Scottish Society for Experimental Medicine.	IIcd
Waddell, G. & Ledingham, I. McA. (1975) ITU flying squad. <u>In preparation</u>.	IId
Waddell, G., Douglas, I.H., Ledingham, I. McA. (1974) Cardiovascular effects of movement in haemorrhagic shock dogs. Critical Care Medicine 2, 68.	IIIa
Waddell, G. (1975) Movement of critically ill patients within hospital. British Medical Journal 2, 417.	IIIbc
Waddell, G. (1975) Movement of critically ill patients. Nursing Times. In press.	IIc, IIIc

SUMMARY

Aims:

1. to document the patho-physiological effects of movement on critically ill patients.

2. to determine the feasibility of transporting critically ill patients to a central ITU.

Studies

Initial retrospective reviews (Part I) helped to plan the main prospective study (Part II) on critically ill patients transferred by ambulance to a central ITU. An ITU flying squad was developed. Initially, clinical monitoring of haemodynamic, respiratory, fluid balance and temperature variables was carried out on 20 patients before, during and after transfer. Similar measurements on 20 convalescent patients showed no change. Thereafter 18 critically ill patients were studied with continuous electronic monitoring of intra-arterial blood pressure, ECG and an accelerometer record of movement. The organisation and function of the ITU flying squad was analysed. The findings were supported by original studies (Part III) on dogs with haemorrhagic shock and on critically ill patients and post-operative patients moved within hospital.

Conclusions

Serious effects of transport are a problem only in critically ill patients. Patients with chest injuries or intra-thoracic bleeding seem to be at particular risk. The effects of transport may be caused directly by movement or indirectly by changed treat-

ment during movement. These indirect effects appear to be clinically more important and can be significantly reduced by an ITU flying squad. Sustained effects seem to be caused indirectly while direct effects are transient. Although not previously reported, hypertension appears to be a much more common response to movement than hypotension. Despite previous concentration on the ambulance ride, the present studies suggest that movement to and from the ambulance or within hospital may be at least as hazardous.

If ITU facilities are to be made generally available, it is suggested that they could be organised on an area basis. An ITU flying squad working from an Area ITU has been shown to be one feasible method.

ABBREVIATIONS

Clinical:

AV	atrio-ventricular	
BP (mm Hg)	blood pressure (millimetres of mercury)	
COP (l/min)	cardiac output (litres/minute)	
CVP (cms H_2O)	central venous pressure (centimetres of water) measured from the fourth intercostal space in the mid axillary line.	
dBA	decibels (unit of noise; an increase of 10 dBA represents a doubling of loudness)	
DBP	diastolic blood pressure	
ECG	electrocardiograph	
g	gravity, unit of acceleration (32ft/sec/sec)	
g.r.m.s.	"g" root mean square	units for vibration
Hertz	frequency in cycles/sec	
HR	heart rate (beats/minute)	
IPPV	intermittent positive pressure ventilation	
ITU	intensive therapy unit	
mBP	mean blood pressure (by electronic integration)	
Po_2 (mm Hg)	arterial partial pressure of oxygen	
Pco_2 (mm Hg)	arterial partial pressure of carbon dioxide	
RAP (cms H_2O)	right atrial pressure	
RR	respiratory rate (per minute)	
SBP	systolic blood pressure	

Battle casualties:

DOW	died of wounds (after reaching medical aid)

Hospitals:

Gartnavel	Gartnavel General Hospital, Glasgow
Western Infirmary	Western Infirmary, Glasgow

INTRODUCTION

The Western Infirmary, Glasgow was a 667 bed general teaching hospital. In 1973 the elective and convalescent wards were redeveloped two miles distant at Gartnavel General Hospital. The idea for the present study arose as the Intensive Therapy Unit (ITU) remained at the Western Infirmary and critically ill patients had to be transferred between the two hospitals. The five bed ITU opened in 1968 and has always accepted patients from district and specialised hospitals in the area. It has a particular interest in shock and respiratory failure. There are separate units for coronary care, renal dialysis and burns and routine post-operative care is carried out in separate recovery rooms. No neurosurgery nor cardio-pulmonary by-pass is performed in the hospital.

Since 1971 the resuscitation of shocked patients has been primarily the responsibility of the Shock Team[1] which consists of a consultant clinical physiologist and three post-fellowship registrars (one from each of the divisions of surgery, anaesthetics and orthopaedics, and normally seconded for a period of one year). Five technicians are also integrated into the service. In addition to laboratory and clinical investigation of shock, the team has clinical responsibility for resuscitation problems and works closely with the ITU and the orthopaedic service. The opportunity for the present study arose when the Shock Team assumed responsibility for transferring patients from Gartnavel to the ITU.

The initial literature review showed that many questions about the effect of transport on critically ill patients remained unanswered. Changes due directly to transport needed to be distinguished from those that were caused indirectly or were coincidental. The detailed patho-physiology, incidence and importance of the reported phenomena required clarification. Could patients at high risk be identified? Which characteristics of transport and movement were most harmful? Did prior resuscitation influence the risk? Measures to prevent or at least to reduce the incidence and severity of these effects remained to be developed.

The aims of the present study were two-fold:

1. to document the patho-physiological effects of movement on critically ill patients.
2. to determine the feasibility of transporting critically ill patients to a central ITU.

Before starting the main study three retrospective reviews (Part I) were made of Scottish mountain rescue transport, obstetric flying squad transport and transfers from other hospitals to the ITU of the Western Infirmary in previous years.

The main prospective clinical study (Part II) was of the effects of ambulance transport. An ITU flying squad was developed. Initially, clinical measurements were made on 20 critically ill patients before, during and after transfer to the ITU. Most of these transfers were over short distances. Similar but non-invasive measurements were made on a control group of convalescent surgical patients. Thereafter, electronic equipment was introduced to permit continuous intra-arterial monitoring and the scheme was extended to include two more distant district hospitals. 11

patients with full intra-arterial monitoring provided the main data in this phase. The organisation and function of the ITU flying squad over the entire period was also analysed.

Further prospective studies (Part III) were made on the effect of movement. Dogs with haemorrhagic shock were subjected to jolting and tilting. Clinical studies were carried out on routine post-operative patients and on critically ill patients moved within hospital.

In all studies several basic criteria were adopted. Reliable, objective measurements were recorded immediately, with detailed timing of events. Proof of stability was obtained by baseline readings before movement. Extraneous factors which might have produced similar effects were excluded as far as possible, especially by maintaining treatment unchanged and uninterrupted throughout the movement.

Previous literature on ambulance transport consisted mainly of limited observations on large numbers of patients, isolated clinical reports or general clinical impression. In the present studies, detailed examination of specific problems by comprehensive physiological measurements of relatively small numbers of patients yielded many original observations.

LITERATURE REVIEW

Battle casualties

Civilian clinical data

Experimental studies on movement

The concept and indeed the contemporary meaning of the word "ambulance" originated from Larrey[2], Surgeon-General to Napoleon's armies. Since then, military surgeons have accepted responsibility for battle casualties from the time and place of wounding. Civilian hospital doctors, in contrast, generally regard their responsibility as beginning only when the patient enters hospital, while family doctors regard theirs as ending when the patient enters the ambulance. This hiatus in medical responsibility during transport is beginning to diminish with the development of obstetric[3], accident[4] and coronary[5] flying squads and mass disaster schemes[6].

The Second Auxiliary Surgical Group[7] clearly showed that delay in reaching medical aid is harmful. In 2863 abdominal wounds mortality increased 0.5% per hour of delay between wounding and surgery although severity of wounding, as judged by the number of organs damaged, was much more important. In 2471 arterial injuries, 37% of those treated within ten hours were amputated, while after 20 hours 63% required amputation. With this clear confirmation of general experience considerable effort has resulted in earlier resuscitation and faster evacuation - in Vietnam the average time from wounding to reaching full hospital facilities was 35 minutes[8,9].

Figure 1 is compiled from official British and American statistics[10-15] with computer-drawn regression lines. Diminishing sickness and the lower mortality of the wounded are the result of improved medical and nursing services, hygiene and surgical technique. Surprisingly, however, the 20% of those hit who die on the battlefield has remained unchanged from the Crimea to Vietnam. Faster evacuation might have been expected to save many lives or at least transfer the statistical allocation of death from "Killed in Action" (i.e. before reaching medical aid) to "Died of Wounds" (DOW i.e. after reaching medical aid). That this has not occurred suggests that faster evacuation is outweighed by the many other factors - medical, military and statistical - which influence this statistic. As with road traffic accidents, there appears to be a considerable proportion of "unsalvageable" cases whose wounds are so severe that they will almost inevitably die on the battlefield. The law of diminishing returns is likely to apply to efforts to save such cases.

Despite the wealth of experience, the crude statistical nature of military data and the multiple aetiological factors limit the extractable information. Battlefields are unsuited to scientific investigations.

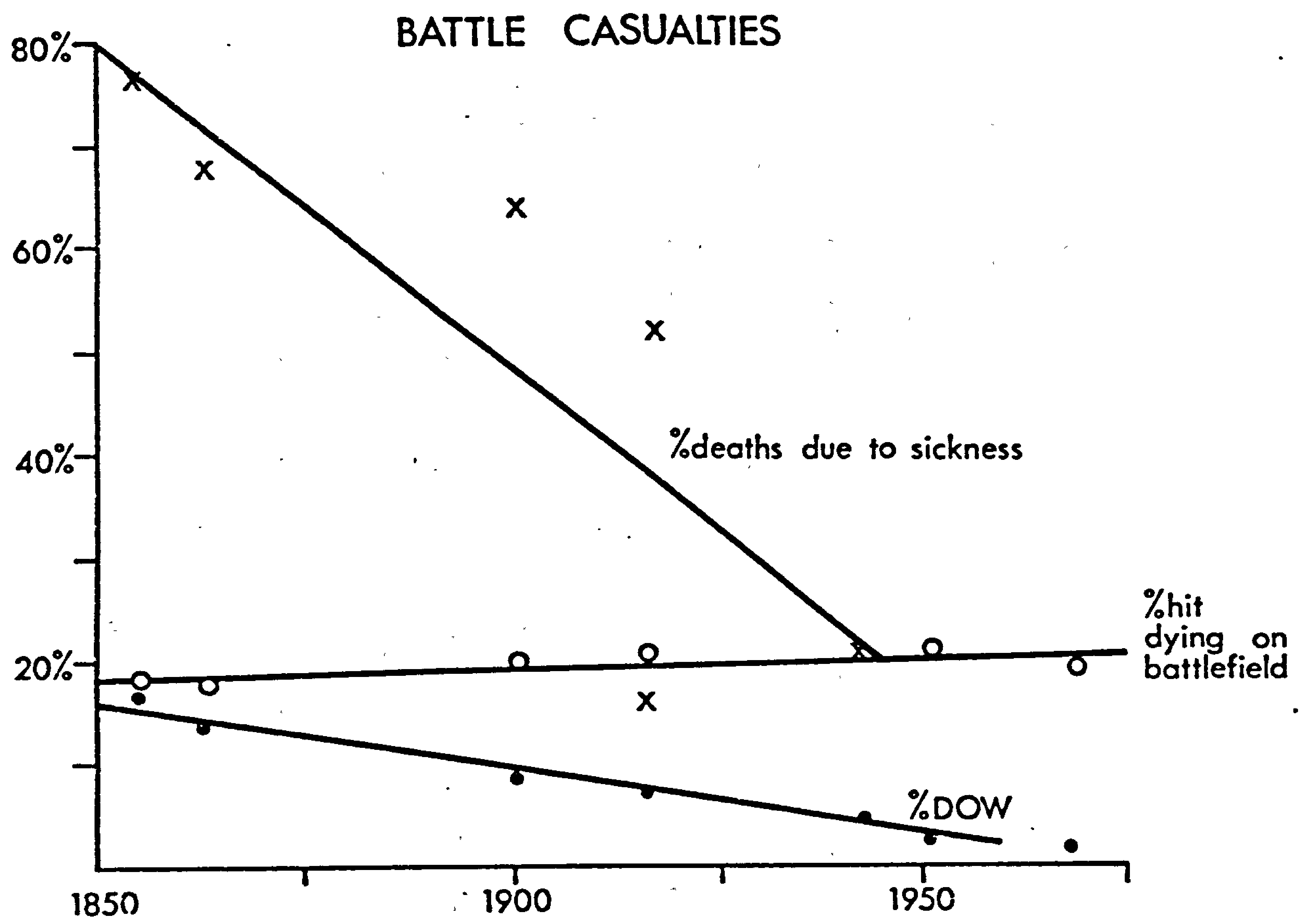

FIGURE 1. Battle casualty statistics in the past century, based on official British and American figures.

Despite a general clinical impression that movement or transport of seriously ill or injured patients can be harmful, factual information is scattered and fragmentary. The available data falls into five categories:

1. data on road accident victims. This is very similar to and suffers many of the disadvantages of battle casualty data. Unstable patients, the unfavourable environment, lack of facilities and the necessity for speed have led to poor evaluation of results and little scientific information.

2. Mobile Coronary Care Units have produced a large volume of ECG data, mainly limited to patients with acute myocardial infarction.

3. more detailed clinical data on patients being transferred to specialised or intensive care units. Most publications in this field are in French from the Parisian Department d'Anesthesiologie and the Laboratoire Experimental de Physique de l'Assistance Publique. Some of these papers give the best data available.

4. very limited information on the movement of patients within hospital.

5. very limited information on the effects of tilting ill patients.

1. Road accidents

Adams[16] reviewed deaths on country roads in Australia. An analysis of place of death according to injury and according to location of accident suggests that death in transit may be a reflection of time from injury and probably unrelated to the journey. Mackay[17], reviewing post mortems of road accident victims, considered some 43% might have had a greater chance of survival if medical treatment had been available at the scene of the accident within ten minutes. Smith[18], however, in a similar review, considered that only 3% might have been saved. London[19], reviewing the ambulance journey to hospital of injured patients, found little evidence of inadequate care during the journey. Nancekievill[20], providing medical care within two minutes of racing car accidents, concluded that severely injured drivers may die at the scene of the accident or in hospital, but "they should not die during transport to hospital".

Snook[21] pointed out that the effect of movement could be direct or indirect. Anxiety, pain and the physical stimuli of movement could directly affect the patient's condition. Indirectly, lack of facilities and the motion of the ambulance could reduce the ability of attendants to provide life-support, affecting the patient by changed or inadequate treatment. Many of the changes seen during the transport of road accident victims may be either coincidental due to their rapidly changing condition so soon after the accident or caused indirectly. The wide divergence of opinion summarised in the previous paragraph may simply be differing estimates of what standard of care is "reasonable". London[22] emphasised the need for "unusually accurate and conscientious records before and after reaching hospital" if any conclusions were to be drawn about transportation. The lack of such records makes it almost impossible to prove any direct effect of the journey to hospital. It is, however, striking that Nancekievill[20], who probably provided close to the ideal initial treatment for road accident victims, found little effect of the journey. A good account of the practical provision of basic care during transport was provided by Pacy[23].

Snook[21] reported one patient with multiple injuries in whom movement of a severely crushed lower leg repeatedly caused a "sharp fall" in BP. Cullen et al[24] reported one patient with multiple fractures who had already had two cardiac arrests and was on IPPV. While being transferred to another hospital vertical jogging appeared to cause clinical shock and a fall in SBP from 110 to 90 mm Hg. They attributed this to movement of a leg fracture. His condition improved soon after the journey. Snook[21] recorded three further patients in whom spasm and pain were associated with movement at a femoral shaft fracture during transport. No other documented case could be found to confirm this generally accepted phenomenon. In fractures of the shaft of the femur the introduction of the Thomas splint in World War I was a major contributing factor to the reduction of mortality during initial evacuation from an estimated 40% to 25%[25]. The Tobruk splint in World War II also appeared to reduce mortality and greatly improve general condition during long evacuation[26,27]. It thus appears almost certain that movement of major fractures during transport can, at least on occasion, cause a deterioration in general condition and even death. It certainly causes increased suffering.

2. Myocardial infarction/ECG monitoring

Patients with myocardial infarction have a high incidence of arrhythmia and death in the first few hours[5,28,29]. Of cardiac patients monitored by a mobile coronary care unit, 23%[30] to 33%[31] have arrhythmias when first seen. Unlike hospital experience, many of these arrhythmias are bradycardias[31] or AV dissociation[32]. One of the main aims of mobile coronary care units is to provide early treatment of such arrhythmias[5,32,33]. Adgey et al[32] state that "the transport to hospital of patients with AV block prior to definitive treatment is clearly hazardous". Lambrew[30] found a higher incidence of clinical deterioration en route to hospital in patients whose initial rhythm was abnormal. By providing initial treatment of those arrhythmias prior to transport the 17%[29] of pre-hospital deaths occurring in the ambulance can be reduced[5,32].

In addition a mobile coronary care unit provides cardio-pulmonary resuscitation for patients who suffer cardiac arrest before or during transport to hospital. Most such arrests are due to ventricular fibrillation. In several series 8% of 246[34], 13% of 285[35] and 30% of 26[29] patients with ventricular fibrillation in the ambulance survived to leave hospital. These patients would certainly have died without treatment. In addition, earlier treatment of other arrhythmias appears likely to have prevented some cases of cardiac arrest developing. The total effect of a mobile coronary care unit on ambulance deaths in cardiac cases can be seen from the claim of Pantridge and Geddes[5] to have reduced the proportion of pre-hospital deaths in the ambulance from approximately 10% to none in 155 cases. In a more accurate study Crampton et al[29] reduced such deaths by 60% ($P < 0.0007$).

Lambrew[37] found that the introduction of improved training for ambulance personnel, ECG telemetry and voice communication between ambulance and hospital markedly reduced the number of collisions in which ambulances were involved. This was presumably due to less urgent dashes to hospital permitted by improved treatment.

The above data proves conclusively that improved standards of care during transport and avoidance of the usual delay in starting treatment during transport can save the lives of patients with acute myocardial infarction. This is the best documented example of the effect of standards of care during transport. However, this could be entirely a matter of dealing with the indirect effects of transport. As already indicated, immediately after a myocardial infarction patients have a high incidence of arrhythmias and cardiac arrest quite apart from any effect of transport. There does not appear to be any evidence that transport causes these arrhythmias and cardiac arrests: they may well be coincidental.

Similarly Lambrew[30] found an 8.7% incidence of significant arrhythmias during transport in 4334 medical and surgical patients (excluding chest pain) and 4.2% in 2744 trauma patients. The incidence of such arrhythmias in similar patients in hospital or similar age groups in the general population is unknown. It appears that these arrhythmias are related to the onset of disease or injury; there is no evidence that they have any relationship to transport.

From this work the only evidence for a direct effect of transport is clinical impression. Crampton[36] noted an apparent increase in the frequency of extrasystoles when patients were lifted on to the stretcher. Lambrew[37] noted an increase in HR when the ambulance siren was switched on, presumably an effect of anxiety.

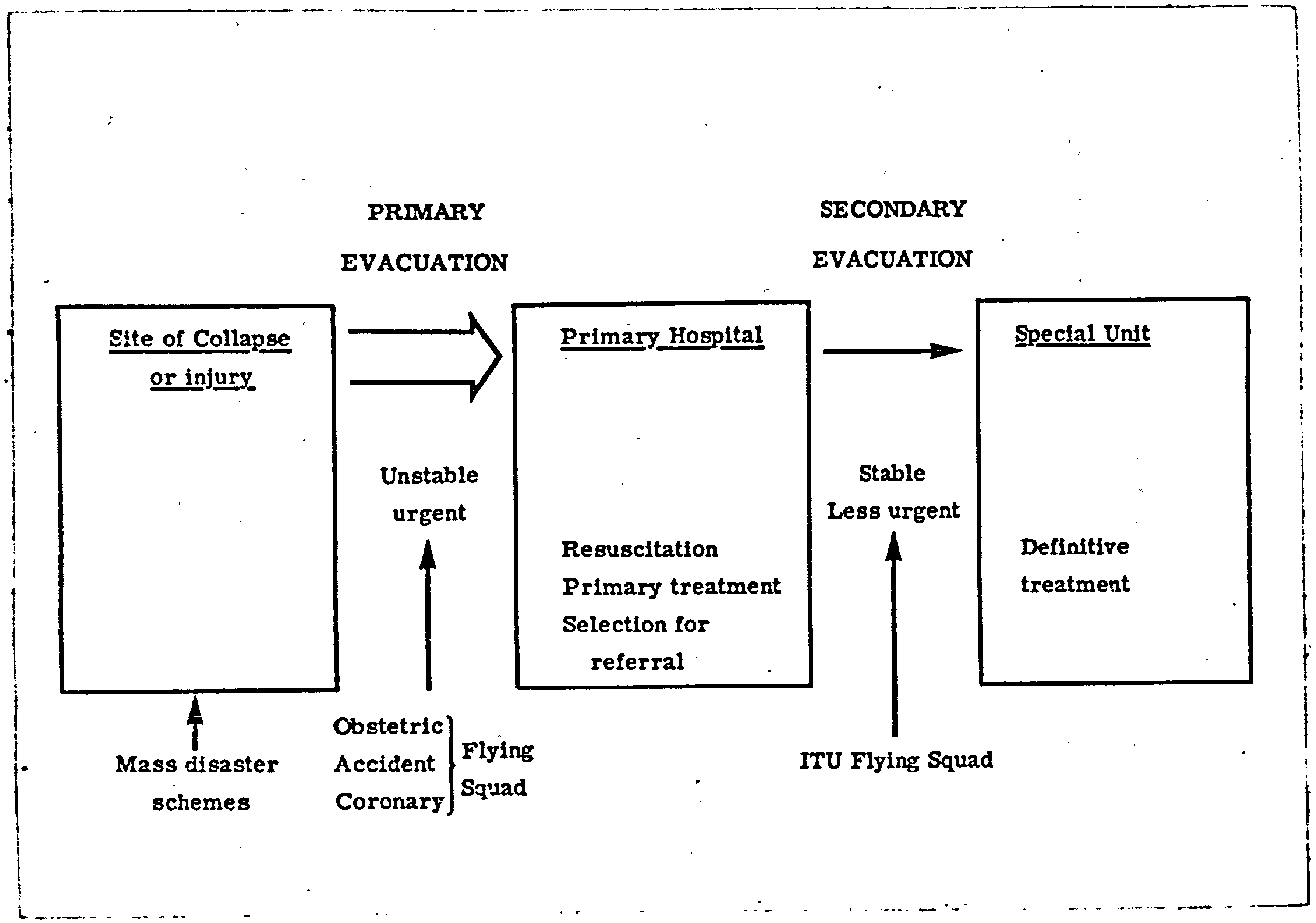

FIGURE 2. Diagrammatic representation of primary and secondary evacuation in civilian practice.

3. Secondary transfer between hospitals

With the possible categorisation of hospitals and the creation of specialised units, inter-hospital transfer of ill patients is unavoidable. Such secondary transfers (Fig. 2) have two advantages over the initial transport of patients to hospital: it is possible to identify patients at high risk who merit intensive allocation of limited resources; there is usually time for adequate preparation for the journey, hence patients can be stabilised before transfer and pre-transfer baseline readings can be obtained.

An excellent review of the problems of organising and running air evacuations is given in the report of a Seminar of the French Association of Anaesthetists[38]. They emphasise the need for adequate preparation for the journey. Endotracheal tubes, tracheostomy, intra-pleural drainage, naso-gastric tubes, intravenous lines and urinary catheters should all be inserted before the journey if likely to be required. Transport should not be regarded as an unavoidable and risky gap in treatment, but as a further positive phase of continuing therapy. Nevertheless, the practical problems and limitations during transport must be clearly recognised as they can only be overcome by adequate planning and preparation. They argue that there is a case for transport being organised and supervised by doctors with a particular interest and experience in this field.

The best analysis of the clinical effect of transport is the review by Pichard et al[39] of ill patients transferred by them in the Paris area in a one year period. Of 430 patients transferred by ambulance, 29% had some incident en route, more than half being a fall in SBP of at least 20 mm Hg. 6.7% had more serious deterioration: arrhythmias, cardiovascular collapse, cardiac arrest, respiratory insufficiency or fits. Smaller groups transferred by helicopter and fixed wing aircraft had no cases of cardiac arrest or arrhythmia: the total incidence of serious incidents however was no different. Lack of detail on patient selection for the different forms of transport makes comparison difficult, though the authors felt that the higher incidence by road was related to higher levels of acceleration and vibration.

The majority of patients were seriously ill and required life-support. Although as far as possible their clinical condition was stabilised before transfer, no baseline data was presented. Some of the changes could be coincidental and there was little proof that they were caused by transport. Nevertheless the authors drew the following conclusions about the changes which did occur:

symptoms arise unexpectedly and do not exist, or are treated, before departure.

they do not appear to be related to insufficient treatment before transport (my emphasis).

they occur after a period of travelling time has elapsed, often related to periods of more violent movement of the vehicle.

they generally settle spontaneously when travel is over.

Patients most susceptible were:

those with cardiovascular instability, especially pulmonary emboli or massive blood loss.

those with serious neurological states, especially conditions liable to fits, encephalopathies or high cervical fractures.

Three patients were reported in more detail:

a six month old baby with whooping cough who had convulsions in a helicopter, apparently related to air turbulence.

a moribund 40 year old man unconscious from an intra-cerebral haemorrhage whose SBP progressively fell from 90 to 50 mm Hg during the last five minutes of an ambulance ride.

an 80 year old woman with a myocardial infarction and AV dissociation on an isoprenaline infusion who had a cardiac arrest when the ambulance was traversing a particularly rough section of road.

Cara et al[40] reviewed 130 patients with respiratory insufficiency transferred by ambulance. They suggest that higher speeds put a greater strain on the patient and advocate police escorts for a smoother journey. Conversely, they also suggest that journeys lasting more than 30 minutes impose a greater cardio-respiratory strain. No evidence was presented for these statements. Two patients died en route, one a child with tetanus who had a cardiac arrest when the vehicle sustained severe jolting.

Transport of unconscious patients between hospitals was reviewed by Hurtaud[41] and Radiguet & Picard[42]. They emphasise the need for safeguarding the airway, if necessary intubating the patient before setting off, for a secure intra-venous line and for smooth rather than fast progress. Hurtaud[41] found that the neurological state deteriorated during the ambulance journey in six of 53 patients with head injuries. However, 20 of the 53 deteriorated while awaiting transport. There was no evidence that the journey caused deterioration.

Cardoso[43] reviewed BP before, during and after an ambulance journey in 581 patients. SBP fell 20 mm Hg or more in 15% of 349 patients with an initial unsupported SBP over 100 mm Hg. A similar fall was seen in 18% of 72 with an initial SBP maintained over 100 mm Hg by noradrenaline and in 31% of 160 whose initial SBP was less than 100 mm Hg despite noradrenaline. Two cardiac arrests occurred in transit.

Poisvert[44] pointed out the risks of transporting patients hyper-excitable due to tetanus. He reported one case of a 58 year old man who developed generalised and laryngeal spasm when the ambulance engine was started. In a five year old child the intravenous infusion containing his drugs was dislodged unnoticed when he was moved to the ambulance. 15 minutes later cardiac arrest occurred during transport. As a result of those experiences they ensured the following before setting off:

a clear airway by intubation or tracheostomy.
adequate sedation for several hours before the journey.
transport under general anaesthesia, neuroleptanalgesics or if necessary curare and IPPV.

As a result of these measures they transported ten consecutive cases without incident, except that one 34 year old female had an increase in HR and a fall in SBP from 110 to 80 mm Hg when the ambulance suffered sudden jolting. Further sedation restored her condition.

Several general conclusions may now be drawn from the literature on ambulance transport. Delay in reaching medical aid is harmful while faster provision of care and improved care in the ambulance can save lives. Clinical deterioration during transport may take the form of hypotension, arrhythmias, fits or acute respiratory insufficiency. 15 - 30% of selected groups of ill patients may deteriorate during ambulance transport. Cardiac arrest during transport may occur in 0.3 - 1.7% of ill patients. Patients at highest risk are:

a) those with cardiovascular instability, especially acute myocardial infarction, massive blood loss or pulmonary emboli;

b) those with serious neurological states, especially conditions liable to fits, tetanus, encephalopathies or high cervical fractures.

There is little evidence that these effects are caused by transport: many may be caused indirectly or may be coincidental. There is, however, a small but consistent number of reports of isolated patients suffering sudden deterioration when the ambulance sustained severe jolting.

4. Movement within hospital

Taylor et al[45], monitoring high risk cardiac patients moved within hospital, found 90% had a rise in HR and two of 50 appeared to develop arrhythmias in response to movement. Weller[46], moving patients to ITU after cardio-pulmonary by-pass, found 11 out of 22 had a rise in BP while three had a fall of up to 15 mm Hg. There was a variable change in HR and no appreciable change in ECG.

5. Tilting

Pugh[47], reviewing mountaineering hypothermia, found suggestive evidence that head up tilt during transport led to fits and death in two patients. Cullen et al[24] claimed that head up tilt has "well-known ill-effects on the blood supply to the brain, which would in many cases be sufficient to cause respiratory arrest and death".

They did not, however, report any cases nor experimental evidence. Stabler[3] reported a woman shocked after an abortion who suffered prolonged fainting each time she was tilted head up. Campbell[48] found no change in BP or COP when cats with haemorrhagic shock were tilted head up or head down.

The conventional naming of the body axes in the supine position is:

X: vertical (up - positive)

Y: transverse (usually left - positive)

Z: longitudinal (head - positive).

Ambulance measurements

Pichard et al[39] measured acceleration and vibration in ambulances by accelerometers strapped to the patient's chest. Sustained acceleration of up to 0.7 g for 20 seconds occurred in the Y axis on cornering and up to 0.85 g for three seconds or 0.3 g for 25 seconds in the Z axis on braking. At 25 - 30 km/hr peak vibration in all axes was in the 1 - 4 Hz range with secondary peaks up to 10 Hz and much less above that level. Peak amplitude of vibration was 1.4, 1.2 and 0.6 g in the X, Y and Z axes respectively. Snook[21], measuring X axis vibration in ambulances, reported 0 - 14 Hz with main peaks of 1 - 3 Hz and amplitude comparable to Pichard et al[39]. Snook[21] found X axis vibration in a research ambulance to increase with speed: 30 mph - 0.095 g.r.m.s.; 40 mph - 0.0104 g.r.m.s.; 50 mph - 0.135 g.r.m.s. The amplitude of vibration on the near-side of the vehicle was greater than on the off-side. Both Pichard et al[39] and Snook[21] found marked variation in vibration with different ambulance design. Pichard et al[39] found both sustained acceleration and vibration much more pronounced in ambulances than in helicopters or aeroplanes.

Mills[49] found that 90% of the time, noise in ambulances was under 75 dBA. On accelerating through the gears peaks of 86 dBA were recorded. Sirens produced peaks up to 95 dBA[21]. In comparison, hospital in-patients tolerate 60 dBA while healthy persons tolerate 70 - 75 dBA on long coach journeys and 75 - 80 dBA on short urban journeys. Lambrew[37] noted a rise in HR in myocardial infarction patients when the ambulance siren was turned on.

Biomechanical measurements

Experimental data on human response to vibration in the supine position is limited, most relating to the aerospace environment. All refers to healthy, young adult male subjects (often only one or two), and the conclusions do not necessarily apply to ill or injured patients. The sustained, single frequency, single axis vibration used is not comparable to an ambulance ride[50], most reported cases of clinical deterioration being related to sudden jolting.

Ten papers report investigations into human biophysical response in the semi-supine[51-54], supine but restrained[55,56] and supine, unrestrained position[57-60]. All concern X or Z axis vibration and none the Y axis, though one[58] used subjects lying on one side undergoing vibration in the vertical axis. Frequencies of 1 - 20 Hz were used. Measurements of hip, abdominal or thoracic displacement and colonic pressure showed a principal resonance of 2.5 - 9 Hz with often one or more secondary resonances up to 19 Hz. The frequency of the principal resonance varies with the build of the individual, position of the body, muscle tensing and peak acceleration[60]. Coermann et al[56] found that rigid or semi-rigid envelopes around the trunk increased the frequency of principal resonance of abdomen and thorax and lowered the frequency and amplitude of resonance of air at the mouth. This may be relevant to Military Anti-Shock Trousers[61].

Psychophysical aspects

Four papers[62-65] report investigations into subjective tolerance of short-term vibration in all three axes. The main limiting factors were thoraco-abdominal discomfort, dyspnoea and headache which at frequencies below 10 Hz limited tolerance to approximately 2 - 5 g. The evidence on relative tolerance of vibration in the different axes is mixed, but at frequencies below 7 Hz toleration of vibration in the Z axis may be lower than that in the X axis. Head restraint, relative head/body movement and the degree of body/couch coupling may influence tolerance[64]. The supine position may not be best for tolerating vibration,[63,65], but with ill patients there is often little choice. Discomfort, moreover, bears little correlation with physiological harm[66].

Physiological measurements

Three papers report the cardiovascular response of supine humans on a vibration table. Mandel[63] found a uniform increase in HR irrespective of body position or axis of vibration. Pichard et al[39] studied groups of five to eight subjects exposed to vibration in the X axis at 5 and 7 Hz for 30 minutes at amplitude 0.5 g and at 10 and 15 Hz for one hour at 0.7 g. No vibration was less than 5 Hz although the main peaks in ambulances lie below this level. BP and COP were measured by non-invasive techniques, the COP measurements being of doubtful accuracy. With 5, 7 and 10 Hz vibration nearly all subjects showed bradycardia and a fall in BP and COP. At 15 Hz four subjects reacted as above, but the other four had a rise in HR, BP and COP. Hood et al[67] report the best study. Four restrained, semi-supine subjects were exposed to seven minutes vibration in the X axis at 2, 4, 6, 8, 10 and 12 Hz with peak accelerations of 0.6 and 1.2 g. Intravascular pressure monitoring showed some artefact and COP was measured by the dye dilution technique. HR, mean arterial pressure, mean CVP and COP all increased, most markedly at 8 - 10 Hz and at 1.2 g. These changes were very similar to those produced by mild leg exercise.

The differing results of Hood et al[67] and Pichard et al[39] are unlikely to be explained by their relatively minor variations in the supine position. No report other than Pichard et al[39] suggests that vibration causes bradycardia. In sustained acceleration of supine humans[68] or vibration of sitting humans,[69] and anaesthetised dogs,[67,69,70] HR consistently increases.

Measurement of BP during vibration is fraught with artefact[70,71]. The integral of a sine wave is zero, so if sinusoidal vibration is added to the BP in a simple algebraic fashion the integrated mean pressure should not be altered appreciably. The pulse wave however is a complex harmonic and each harmonic will be affected by the vibration. The physical effect of vibration on the elastic reservoir formed by the vascular system is shown by the rise of up to 40 mm Hg in arterial pressure on vibrating dead dogs[71]. Catheter whip may produce an increment of up to 5 mm Hg when the axis of vibration is perpendicular to the catheter[71]. The transducer itself may be markedly affected by vibration or acceleration[70], though more recent transducers are likely to be less affected. Finally, if a physical print-out system is exposed to vibration this may introduce another artefact, while electro-magnetic recording might experience "noise" in an ambulance environment.

The above problems in intravascular pressure recording probably make the reported changes in CVP meaningless. They may also partly explain the disagreement of reported changes in BP. Most artefacts increase the observed reading and it is striking that the group who devoted most attention to eliminating artefact[70,71] reported a slight fall in BP in anaesthetised dogs. It may be that the relatively unsophisticated clinical measurement of BP by Pichard et al[39] is as reliable as the intravascular measurements of Hood et al[67]. The fall in BP reported by Pichard et al[39] was supported by the simultaneous appearance of pallor, cold sweats and a feeling of fainting.

The fall in COP reported by Pichard et al[39] differs from most other reports and is derived from an unsatisfactory technique. Hood et al[67] reported a rise in COP which is supported by the rise observed on vibration of seated humans[69] and anaesthetised dogs[67,69].

The above changes in BP and COP are consistent with a fall in peripheral resistance[67]. In contrasting the differing results it should be noted finally that the results of Pichard et al[39] disagree with those of virtually all other reports.

The mechanism of these cardiovascular changes is not clearly understood. Possibilities are: increased muscular activity in resisting movement[63]; stimulation of muscle stretch receptors giving a reflex increase in muscle tone[67,69]; or a venous pump effect[67]. There may be a more central stimulation of intra-abdominal or pulmonary stretch receptors[69] or baroreceptors in the great veins, aortic arch or carotid sinus[39,69]. There is sensory input from skin and locomotor structures[39] and from the semicircular canals[72]. Finally, in conscious humans, there are important psychological influences[50]. All are hypotheses and no single mechanism is likely.

The observed changes in different circumstances are probably due to varying combinations of many or all of these factors.

Hood et al[67], using similar measuring techniques, found that conscious semi-supine humans and anaesthetised dogs showed a comparable rise in HR, BP, COP and oxygen consumption in response to vibration. Clark et al[69] found that the initial response differed, anaesthetised dogs having a fall in mean arterial pressure of 27 mm Hg within 30 seconds and unsedated, sitting humans having no fall. Once a steady state was reached however, their findings confirmed those of Hood et al[67].

Two papers report respiratory changes in supine humans on a vibration table. Hood et al[67] found a rise in minute volume and oxygen consumption, but no significent change in arterial pH, P_{CO_2} and P_{O_2}. Dixon et al[73] reported increased minute volume and oxygen consumption which was lowest in the supine position. They also found that in some subjects ventilation was in excess of metabolic demand with a fall in end-tidal CO_2 tension. Ernsting (quoted by Dixon et al[73]) found hyper-ventilation to increase with amplitude and frequency of vibration. The above changes are similar to those reported in sitting humans[74,75]. The mechanism of the respiratory changes is unknown, but may be similar to those discussed for the cardiovascular changes.

Motion sickness

Manning and Stewart[72] found that on a swing the supine position had the lowest indicence of motion sickness. Walsh found that sensations aroused by slow oscillations (0.1 Hz) were incorrect in their timing which may influence motion sickness. Both studies found less motion sickness if visual orientation was permitted. Relative head/body movement may also be important[50].

PART I : RETROSPECTIVE REVIEWS

a) Mountain rescue transport

b) Obstetric flying squad transport

c) ITU transfers

Ia : MOUNTAIN RESCUE TRANSPORT

Mountain rescue provides the most prolonged and arduous stretcher journeys in civilian practice. Seriously ill or injured mountaineers lie unattended for some hours before help arrives: after minimal first aid they are then subjected to several miles and often many hours of movement. Despite the greatest care by skilled and dedicated men, carrying a stretcher by hand across rough and treacherous ground, often in the dark, inevitably produces jolting and discomfort.

Under such conditions, detailed medical records are unobtainable: recourse must be had to simpler analysis of large numbers of cases. In this way, Pugh[47] found suggestive evidence that head up tilt during stretcher transport caused fits and death in two patients with exposure. There is no other report on the detailed circumstances of mountaineering deaths or on the effects of mountain rescue transport.

The present analysis is of deaths occurring in Scotland from 1960 to 1972 inclusive. Table I shows the total numbers reported by the Scottish Mountain Rescue Committee and published annually in the Scottish Mountaineering Club Journal. Aircraft crashes are excluded as virtually all victims died immediately. All other causes are included - injury, exhaustion and exposure or "heart-attack". Possible deaths during the stretcher journey were identified from the above source, supplemented by reference to the leaders and records of all the main mountain rescue teams in Scotland. All sudden or accidental deaths are reported to the Crown Office, who made available their full records on deaths of possible interest.

TABLE I

Scottish mountaineering accidents (1960 - 1972)

TOTAL CALL-OUTS:		
	(Includes false alarms, searches, crag-fast, minor injuries and illness)	715
PATIENTS CARRIED DOWN ALIVE:		
	(Injury 80% Collapse 20%)	200
DEATHS:		
	(Injury 80% Collapse 20%)	
	At scene of collapse or injury:	160
	On stretcher:	5
	In hospital:	10
	TOTAL DEATHS:	175

Aircraft crashes excluded.

Case reports

In only five cases was death found to occur in transit. All were previously healthy males aged 17 - 26 years. Two occurred in 1962, one in 1965 and two in 1971; two in March, and one each in April, October and December. Two occurred in the Ben Nevis area, two in the Cairngorms and one in Aberdeenshire. None of these factors differ from the overall pattern of Scottish mountaineering accidents.

Case I

This man progressively collapsed from exposure and was assisted by members of his party for several miles. He was then carried one mile on a rope stretcher to a hut. When put on to the stretcher he was conscious, but by arrival at the hut he had stopped speaking, appeared to be unconscious and only moaned slightly at times. On arrival at the hut, his clothes were cut off and he was dried and wrapped in dry clothes in an attempt to restore circulation. One and a quarter hours after arrival at the hut, his pulse could not be felt and artificial respiration was applied for two hours without success. Death was certified as due to exhaustion and exposure followed by cardiac arrest.

Case 2

This man progressively collapsed from exposure. He was assisted by members of his party for approximately one hour, covering one mile downhill before he was unable to go any further. When a stretcher party arrived shortly thereafter he appeared to be unconscious. He was carried quarter of a mile downhill on a Thomas stretcher to a well-heated shelter. On the stretcher he made moaning noises. In the shelter his wet clothes were removed and a warm sleeping bag and hot water bottles put around him. Shortly afterwards he had a fit, and ten minutes later his breathing and pulse stopped. Artificial respiration was continued until a doctor arrived and certified that he was dead. Approximately one hour passed between arrival at the shelter and certification of death.

Case 3

This unusually powerfully built man fractured his right ribs 4 - 10 posteriorly in an avalanche. The eighth rib lacerated the mid-zone of the lung with underlying intra-pulmonary haemorrhage, collapse of the lower lobe and a one pint haemothorax. There was also complete separation of the pubis with a large intra-parietal haematoma and an internal laceration of the liver. There was no significant head injury (from post mortem).

Shortly after the accident, he regained consciousness and his companions made a snow hole for him. Approximately six and a half hours later a rescue party arrived, at which time he was still conscious. He was carried three miles on a mountain rescue stretcher and then three and a half miles by Land Rover, the total journey lasting three hours. On arrival, the local doctor found that he was still alive but very weak and gave him an injection of Coramine. Ten minutes later he died. Death was considered to be caused by haemorrhagic shock (post mortem).

Case 4

This man fell 600 feet in a snow and ice filled gully. He was breathing despite major head injuries when put on to a stretcher by local climbers. After a short distance the party was met by the Mountain Rescue Team, and an accompanying doctor found that he was dead. Death was certified as due to a fractured base of skull.

Case 5

This man fell 400 feet down a snow slope on to scree at 3.20 p.m. When found he was unconscious. At 4.30 p.m. local climbers began moving him by stretcher. After more than a mile he was transferred, still on the same stretcher, to a tracked Snow Tractor. After a further three miles he stopped breathing at 8.00 p.m., 100 yards from a waiting ambulance. A doctor in the ambulance certified death as due to a fractured skull.

The ten deaths in hospital all occurred a period of time after admission. No evidence was found of the journey contributing to these later deaths.

Discussion

Only five of 175 mountaineering deaths occurred during the stretcher journey, while 200 patients, many of them seriously ill, were carried down alive. Two of the five deaths in transit were due to exposure, three to injuries.

In the two deaths from exposure, the patients' condition appears to have worsened during the stretcher journey. The delay in starting treatment might have been avoided by setting up a tent and allowing the casualties to re-warm before moving them[47]. Such a course, however, presupposes that the team can provide adequate shelter and warmth for both casualty and team members in extreme conditions of terrain and climate, and can exclude injuries requiring hospital treatment. Such logistics and responsibility are not always practical. A more recent alternative is the use of improved casualty bags with much better insulation. No deaths in transit from exposure have occurred since the introduction of these bags, which have undoubtedly contributed to the 40 exposure victims carried down alive.

Of the three deaths from injury, only in Case 3 did death appear to be due to blood loss from injuries which, with prompt hospitalisation, might not have been fatal. The time sequence suggests that bleeding may have been restarted by the movement of either the stretcher or the vehicular journey. The combination of chest and pelvic injuries is uncommon in mountaineering: climbers with serious trunk injuries may be especially suitable for helicopter evacuation when this is feasible. In the two deaths from head injuries there is no evidence that the journey was harmful. 150 patients with injuries, many of them serious, were carried down alive.

Table I supports the view[77,78] that, were doctors to accompany mountain rescue teams, they would be unlikely to produce a significant improvement in the mortality statistics. Any major improvement is likely to depend on reaching ill or injured mountaineers more rapidly, as 90% of deaths occur before the arrival of the Mountain Rescue Team. In addition, a greater willingness by exposure victims to stop and seek shelter would retard the cooling process while awaiting the arrival of the team[79].

Detailed medical observations during the stretcher journey would be necessary to prove conclusively that movement caused no harm. Death during, or as a result of, the journey is but a crude index of the gravest effects. Nevertheless this review, despite its inherent limitations, has shown surprisingly little evidence of harm from mountain rescue transport. With 200 patients carried down alive, only five died during the journey and ten later in hospital. The most critically ill patients die before help arrives: those who survive this initial period generally appear able to withstand the unavoidable journey to hospital.

Ib : OBSTETRIC FLYING SQUAD TRANSPORT

The original function of the obstetric flying squad was to increase the safety of domiciliary midwifery, and Stabler[3] was of the opinion that if the patient was fit to transport to hospital, it was not a case for the flying squad at all. Liang[80]. however, concluded that the main function of the flying squad is now the resuscitation and transfusion of the shocked and bleeding patient, and the transfer of such a patient to hospital, where more definitive treatment can be carried out.

No detailed study of the effect of transport on the pregnant patient exists. This review assessed the effect of ambulance transport on obstetric emergencies under the care of a city teaching hospital flying squad.

Results

In 1972 the obstetric flying squad of the Queen Mother's Hospital, Glasgow was called 101 times. Records were available on 98. 91 patients were actively bleeding and intravenous fluids were begun in 47 before the journey. Four patients were clinically shocked. The policy was to begin resuscitation and transport the patient to hospital as soon as possible, not spending long periods on resuscitation before transport, nor performing any obstetric manoeuvres outwith hospital.

Maternal HR and BP were recorded before and after the journey (Table II). In an attempt to assess the effect of the journey separately from the effect of treatment, patients who had no intravenous fluids were similarly analysed with virtually identical results. The slight fall in mean SBP can be accounted for by a number of patients whose initial hypertension (SBP 140 - 160 mm Hg) settled to more normal values over the period of the journey. No patient's readings gave any evidence of serious worsening of the cardiovascular state. No patient showed clinical deterioration. Table III shows that patients with an initial HR over 110/min., or clinical shock, had a significantly more labile BP ($P < 0.001$ χ^2 test). This may simply illustrate that patients actively compensating for haemorrhage have a more labile BP: there is no proof that it was an effect of transport. In 14 patients with antepartum haemorrhage, mean foetal HR was 143/min both before and after transfer. There were no maternal deaths in the series, all patients surviving to leave hospital.

TABLE II

Cardiovascular readings before and after the ambulance journey to hospital (88 patients)

	*Before Journey	*After Journey
Heart rate (beats per min.)	92 ± 12	89 ± 11
Systolic blood pressure (mm Hg)	127 ± 14	123 ± 15(1)
Diastolic blood pressure (mm Hg)	78 ± 9	76 ± 11
Pulse pressure (mm Hg)	50 ± 10	47 ± 9

*Mean ± S.D.

(1) $P < 0.05$ Paired "t" test.

TABLE III

Obstetric flying squad : significance of initial heart rate

		Change during transport	
Initial HR	No. of patients	SBP fell $\geqslant$ 20 mm Hg	SBP rose $\geqslant$ 20 mm Hg
$<$ 100	75	10	1
$>$ 110	10	4	2
Clinically shocked	4	2	0

Discussion

The type of patient to whom the flying squad is called appears to be changing. Improved antenatal care and a hospital confinement rate of 97.3% in Glasgow[81] has reduced the number of intrapartum and third stage problems[3,80,82]. Antepartum haemorrhage is now the commonest reason for calling the flying squad. Only four patients were clinically shocked, mostly in early pregnancy. There may now be a case for greater use of the flying squad for early pregnancy.

No patient deteriorated clinically during the ambulance journey. Table II shows that there was no clinically significant change in cardiovascular readings. This contrasts with isolated cases of clinical deterioration previously reported by obstetric flying squads. The ambulance journey had no effect on foetal HR in patients with antepartum haemorrhage. The present lack of observed effects of transport may be related to the changing pattern of pathology, but the lack of objective and pre-transfer data in earlier reports makes comparison uncertain.

When adequate treatment is available from a flying squad, ambulance transport of obstetric emergencies appears to have little effect on mother or foetus.

Ic : ITU TRANSFERS

To assist planning the prospective study (IIa) of critically ill patients transferred from other hospitals to the ITU of the Western Infirmary, a retrospective review of such transfers was carried out. Similar reviews of secondary evacuation between hospitals of selected groups of ill patients have been reported by several French authors[39-44]. Serious collapse, arrhythmias, cardiac arrest, acute respiratory insufficiency or fits were reported to occur in 5% of such patients and 15 - 30% had a fall in SBP of more than 20 mm Hg.

Results

In six years 67 patients were transferred by ambulance from other hospitals to the ITU of the Western Infirmary. Adequate records were available on 46.

The primary clinical conditions for which transfer was deemed necessary are indicated in Table V(p 68). Patients were transferred when they became acutely ill, ten were transferred on IPPV and the final mortality of the group was 39%. Although there were no statistically significant changes in mean HR or BP as a result of the journey, considerable variation in haemodynamic response occurred from patient to patient. 27 patients had no change in HR or BP. In six patients an elevation of SBP of 30 - 50 mm Hg occurred which settled spontaneously in 2 - 4 hours (Fig. 3) In six patients a fall in SBP occurred of more than 40 mm Hg to under 80 mm Hg. Since urgent treatment was required to correct this hypotension, spontaneous recovery could not be assessed (Fig. 4) A delayed fall in SBP of 20 - 30 mm Hg occurred 1 - 1½ hours after transfer in seven patients (Fig. 5). One previously stable patient developed fits and tachycardia 14 minutes after the journey. Table V(p68) shows the distribution of response within the series. Septic shock appears particularly likely to be associated with either hypertension or hypotension ($P < 0.005$, Fisher's exact test). Patients with chest injuries appear more likely to develop hypertension ($P = 0.05$, Fisher's exact test). Delayed hypotension was evenly spread among the groups.

In the 13 patients for whom respiratory data were available, there were no statistically significant changes in mean RR or arterial blood gases (Table VII - p70). Most of these patients had respiratory failure or crushed chests. No patient had a rise or fall in Po_2 of more than 10 mm Hg or a fall in Pco_2 of more than 10 mm Hg. Six of the 13 patients had a rise in Pco_2 of 12 - 31 mm Hg.

In 28 patients with temperature readings, mean oral temperature before transfer was 36.5°C and mean rectal temperature after transfer was 36.8°C. The one patient to develop hypothermia was moribund from a sub-arachnoid haemorrhage and only one reading was taken before transfer. It appears likely that her hypothermia was unrelated to the journey. Patients whose initial temperature was 36°C or less had a significantly higher incidence of immediate cardiovascular response to the journey ($P < 0.04$, Fisher's exact test). Patients who had an operation within the few hours prior to transfer also had a slightly higher incidence of cardiovascular change. No other pre-transfer parameter was of any prognostic significance.

No deaths occurred within 20 hours of the journey. The final mortality of transferred patients was comparable to that of similar patients treated in the unit whose primary admission had been to the Western Infirmary. The final mortality in patients who developed hypertension (67%) or hypotension (50%) was significantly higher ($P < 0.05$ χ^2 test) than in patients with no change (31%) or delayed hypotension (29%). In half the patients a possible cause for these changes was recorded. In five the patient's condition was unstable and possibly changing before transfer, in seven there was an alteration in IPPV during transfer and one was receiving a Syntocin infusion.

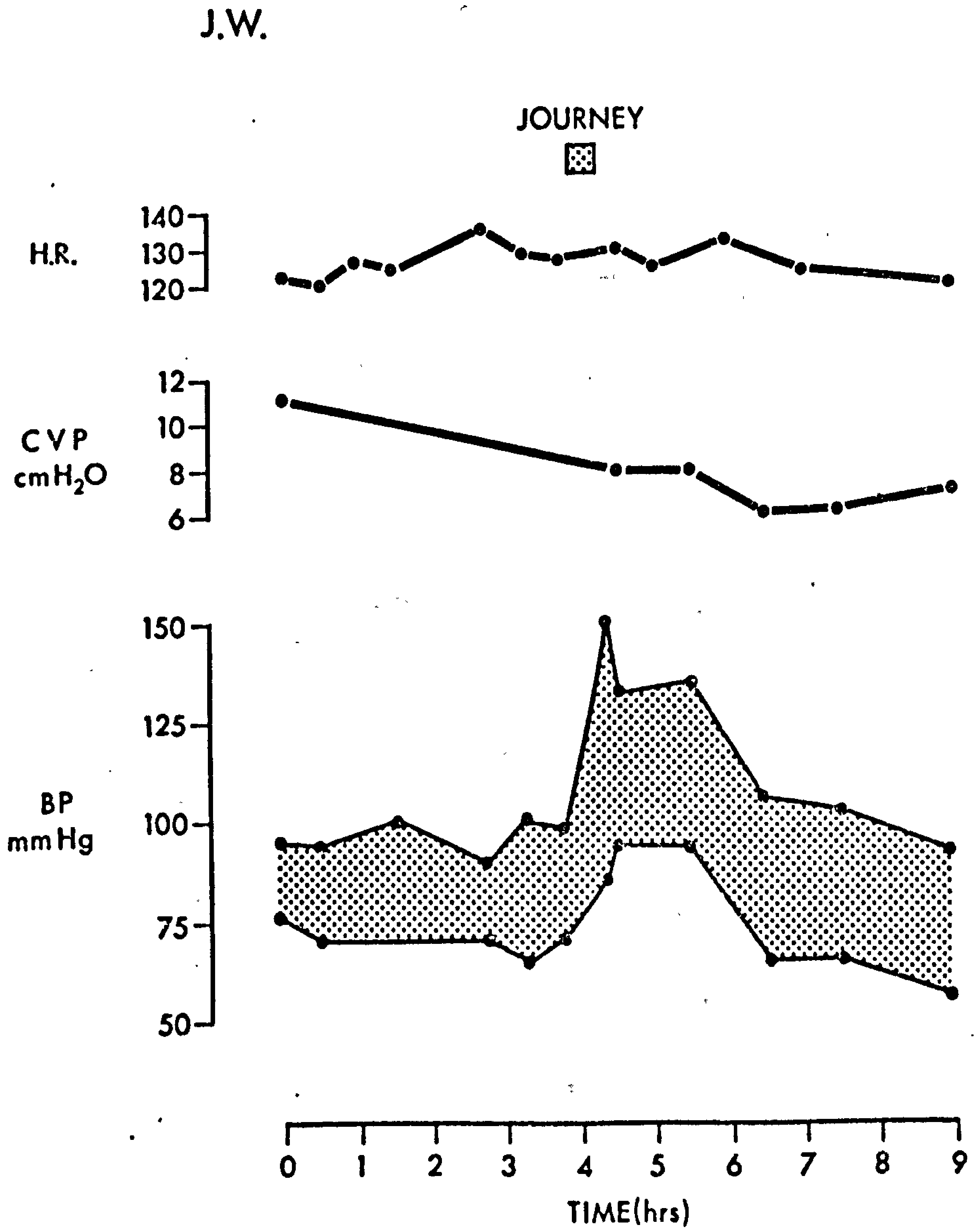

FIGURE 3. ITU review: one example of the hypertensive response to an ambulance journey seen in six of 46 patients.

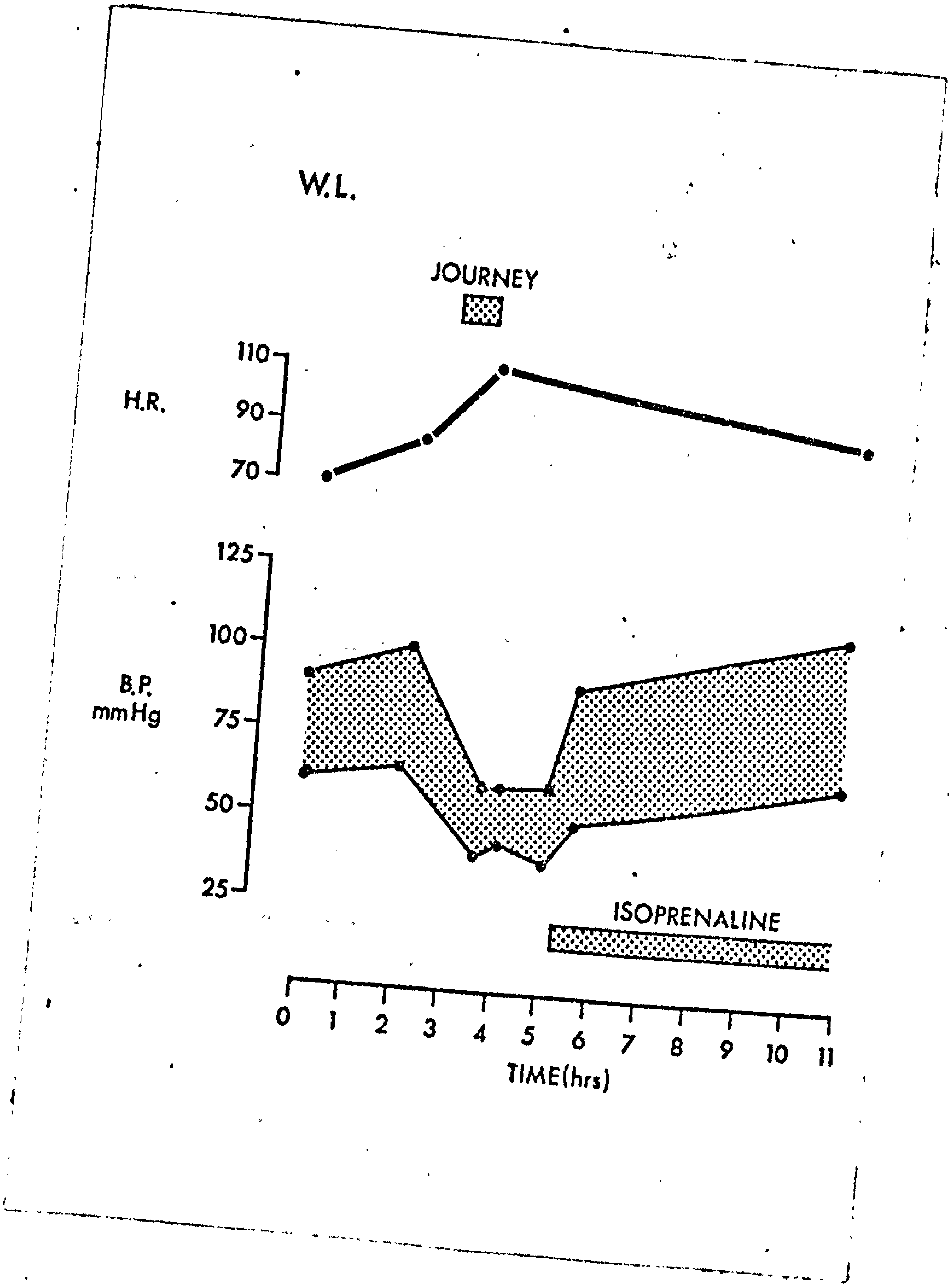

FIGURE 4. ITU review: one example of the hypotensive response to an ambulance journey seen in six of 46 patients.

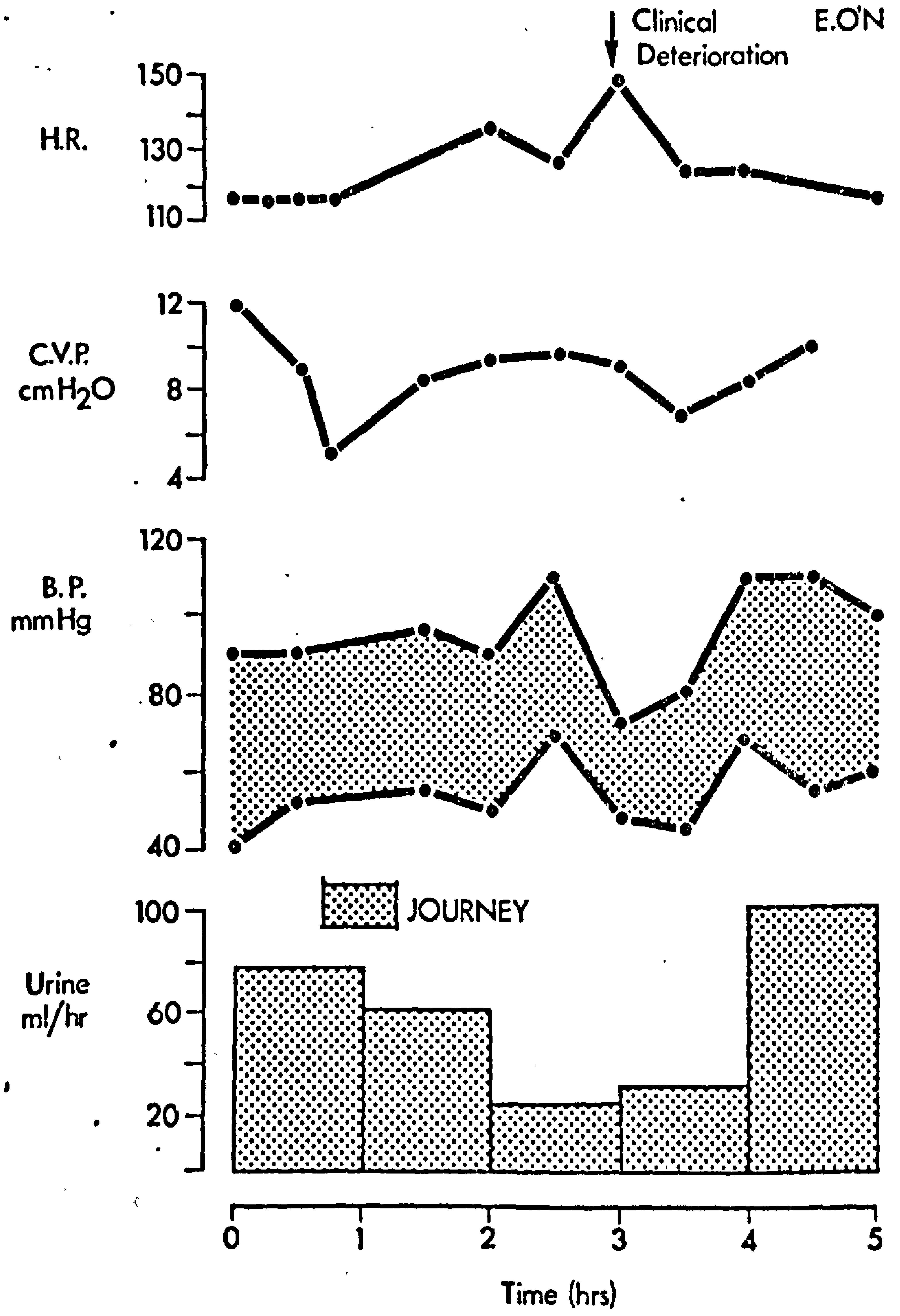

FIGURE 5. ITU review: one example of the delayed hypotensive response to an ambulance journey seen in seven of 46 patients.

Discussion

The incidence of major cardiovascular change seen in this review was comparable to that reported by other authors dealing with similar patients[39,43]. No previous reports, however, have been made of hypertension or delayed hypotension, though the former would seem a not unnatural response to the stress of transport. The records were not sufficiently detailed to determine if "delayed hypotension" was an after-effect of the journey or due to changed treatment after arrival at the ITU, but the timing was remarkably consistent. These findings emphasise the importance of examining patterns and trends rather than spot readings.

The increased incidence of cardiovascular change during transfer in patients with a subnormal body temperature and the higher final mortality in patients who showed such changes suggests that iller patients are more likely to show an immediate cardiovascular response to the journey. This does not, however, suggest that the cardiovascular changes caused death: all patients appeared to recover from these changes before dying. Nor does it prove that movement caused these effects: iller patients may simply be more unstable. In some patients changes in treatment during the journey, particularly changed methods of IPPV, may have contributed to the cardiovascular changes. There was, however, no increased incidence of cardiovascular change among patients on IPPV. Nevertheless it appears that some of the changes might have been caused indirectly and might be prevented by improved care during the journey. This emphasises the importance of maintaining treatment with as little change as possible in any prospective study into the effects of transport.

No previous report has been made of increased Pco_2 in ambulance transport. In this study, 46% of patients with blood gas data showed a rise in Pco_2. This is of particular clinical significance in such patients with respiratory failure or crushed chests. No information was available on the cause of this deterioration.

The phenomena revealed by this retrospective review provided the necessary guidelines for planning the type and duration of observations in the prospective study of ambulance transport (Study IIa).

PART II : PROSPECTIVE STUDIES ON AMBULANCE TRANSPORT

a) Clinical monitoring of ITU transfers

b) Clinical monitoring of convalescent surgical patients

c) Electronic and intra-arterial monitoring of ITU transfers

d) Organisation and function of an area ITU flying squad

Discussion

IIa : CLINICAL MONITORING OF ITU TRANSFERS

The aim of this study was to examine patho-physiological changes in a group of critically ill patients during ambulance transfer from other hospitals to a central ITU (Western Infirmary). French authors[39-43] have reported similar secondary evacuation, but have mainly concentrated on the incidence of hypotension and on major clinical events such as arrhythmias, cardiac arrest, acute respiratory insufficiency and fits. The present study aimed to provide detailed objective measurements on a relatively small group of patients. In the light of the retrospective review (Study Ic) clinical observations were supplemented by cardiovascular, respiratory, fluid balance and temperature parameters for a one hour baseline before movement, in the ambulance at the start and finish of the journey and for two hours after cessation of movement to detect any delayed effect. Every effort was made to maintain treatment unchanged throughout transfer to minimise indirect effects. Although this experimental protocol would not detect any transient phenomena during the ambulance ride, it was hoped to provide detailed documentation of the sustained changes found in the retrospective review (Study Ic).

Patients and methods

The ITU "flying squad" consisted of one or two medical members of a previously described ITU "Shock Team"[1]. When the ITU received a request for a transfer, the flying squad travelled to the referring hospital, set up monitoring equipment and began treatment. They accompanied the patient in an ambulance of standard design and continued treatment on arrival at the ITU.

Quarter hourly readings were made of HR, BP, CVP, toe temperature and RR for one hour before the journey, in the ambulance at the start and finish of the journey and for two hours thereafter. HR was measured by palpation of the pulse or counting from the ECG. BP was measured by arm cuff, mercury manometer and auscultation. CVP was measured by a saline manometer connected to a central venous catheter whose position was confirmed by chest X-ray. The zero reference was the mid-axillary line in the fourth interspace. Toe temperature was measured by a Grant thermometer with a small thermistor taped to the big toe (accuracy ± 0.3°C). RR was counted.

Rectal temperature was recorded on the Grant thermometer using a rectal thermistor taped in position (accuracy ± 0.3°C). Readings were made one hour before, immediately before, immediately after and one and two hours after the journey. A 20 second lead II ECG was recorded at the same intervals on a portable, battery-operated recorder (Transrite II). The bladder was catheterised and emptied and urine production measured over the hour before transfer, the period of the journey and each of the two hours thereafter. Fluid transfused was recorded over the same periods.

A 2 ml heparinised sample of arterial blood was taken by radial stab immediately before the journey. The syringe was sealed with a plastic cap and stored in a vacuum flask containing ice and water. A second sample was taken immediately after the journey. Blood gases on the two samples were measured using standard apparatus (Radiometer system). Preliminary experiments showed that storage in this manner for up to two hours did not introduce clinically significant errors (Table IV).

21 critically ill patients were referred for transfer from other hospitals to the ITU. One patient was considered unsuitable for transfer - after ventricular fibrillation during tonsillectomy. She was unresponsive to pain, had fixed dilated pupils, no spontaneous respiration, a SBP of 40 - 50 mm Hg, a bizarre ECG and a rectal temperature of 35°C. She died within 30 minutes of this decision. 20 patients were transferred. The clinical conditions of this group were comparable to those in the retrospective study, with the exception that there were no chest injuries (Tables V & VI). 15 patients were transported two miles and five from 4.5 - 13 miles. The average ambulance ride was 12 minutes and the total time from bed to bed 33 minutes.

Results

There was no change in the mean cardiovascular variables of the 20 critically ill transfers (Fig. 6). Unlike the patients in the retrospective review (Study Ic), variations in haemodynamic response from patient to patient in the prospective study were minimal (Table V). In no patient did ECG pattern alter. One patient became hypertensive (Fig. 7) but BP had begun to rise before the journey.

the rise appeared to result from an intravenous infusion of plasma and mannitol, rather than from the journey. No patient became hypotensive. Four patients developed delayed hypotension similar to that seen in the retrospective review (Fig. 5 - p59). In three, this was related to starting IPPV.

There was no change in mean RR or arterial blood gases in the critically ill transfers (Table VII). One patient had a fall in Po_2 and two a rise in Pco_2 - all apparently caused by withdrawal of oxygen therapy during the journey or the use of intravenous morphine.

Transfusion requirements slowly diminished with progressive resuscitation (Fig. 8), the rate being uninfluenced by the journey. Urine production slowly increased, again uninfluenced by the journey.

There was no change in mean rectal temperature (Fig. 9). No patient had a change of more than 0.5°C. There was a slight fall in mean toe temperature. Ambient temperature is also illustrated, the sharp falls corresponding to the moves to and from the ambulance. In Figure 9 the "control" values shown are the results of Study IIb on convalescent surgical patients.

One fit occurred 15 seconds after the ambulance moved off, in a patient with a post-partum intra-cerebral haemorrhage. Fits had been controlled with muscle relaxants and IPPV for the previous three hours.

TABLE IV

Effect of storage on samples for blood gas analysis (mean of ten samples)

	0	1 hour	2 hours
Po_2 (mm Hg)	134	132	132
Pco_2 (mm Hg)	52	52	51
pH	7.34	7.34	7.33
Base excess (meq/l)	0	0	-1

TABLE V

Primary condition and cardiovascular response to an ambulance journey

Primary Condition	Retrospective review: Study Ic (46 patients)				Flying Squad: Study IIa (20 patients)			
	No Change	Hypertension	Hypotension	Delayed hypotension	No Change	Hypertension	Hypotension	Delayed Hypotension
Cardiac shock	4	0	0	1	1	0	0	0
Haemorrhagic shock	2	0	1	1	3	0	0	0
Septic shock	3	2	3	0	5	1	0	1
Respiratory failure	7	0	2	1	4	0	0	2
Chest injury	5	4	0	1	0	0	0	0
Coma	5	0	0	2	1	0	0	1
Renal failure	1	0	0	1	1	0	0	0
TOTAL	27	6	6	7	15	1	0	4

TABLE VI

Comparison of retrospective and flying squad patients

	Retrospective (Study Ic)	Flying squad (Study IIa)
Number of patients	46	20
Mean age (years)	42	57
% males	61	65
Pre-transfer SBP less than 100 mm Hg	28%	40%
On IPPV before transfer	22%	10%
Deaths within 24 hours of transfer	6.5%	5%
Final mortality	39%	45%

TABLE VII

Mean respiratory rate and arterial blood gases before and after transfer

	Retrospective review: Study Ic (13 patients)		Flying squad: Study IIa (20 patients)	
	Before transfer	After transfer	Before transfer	After transfer
Respiratory rate (per minute)	33	30	26	28
pH (units)	7.35	7.35	7.36	7.39
Pco_2 (mm Hg)	46	52	41	41
Po_2 (mm Hg)	60	65	102	97
Base excess (meq/l)	-2	0	-2	-1

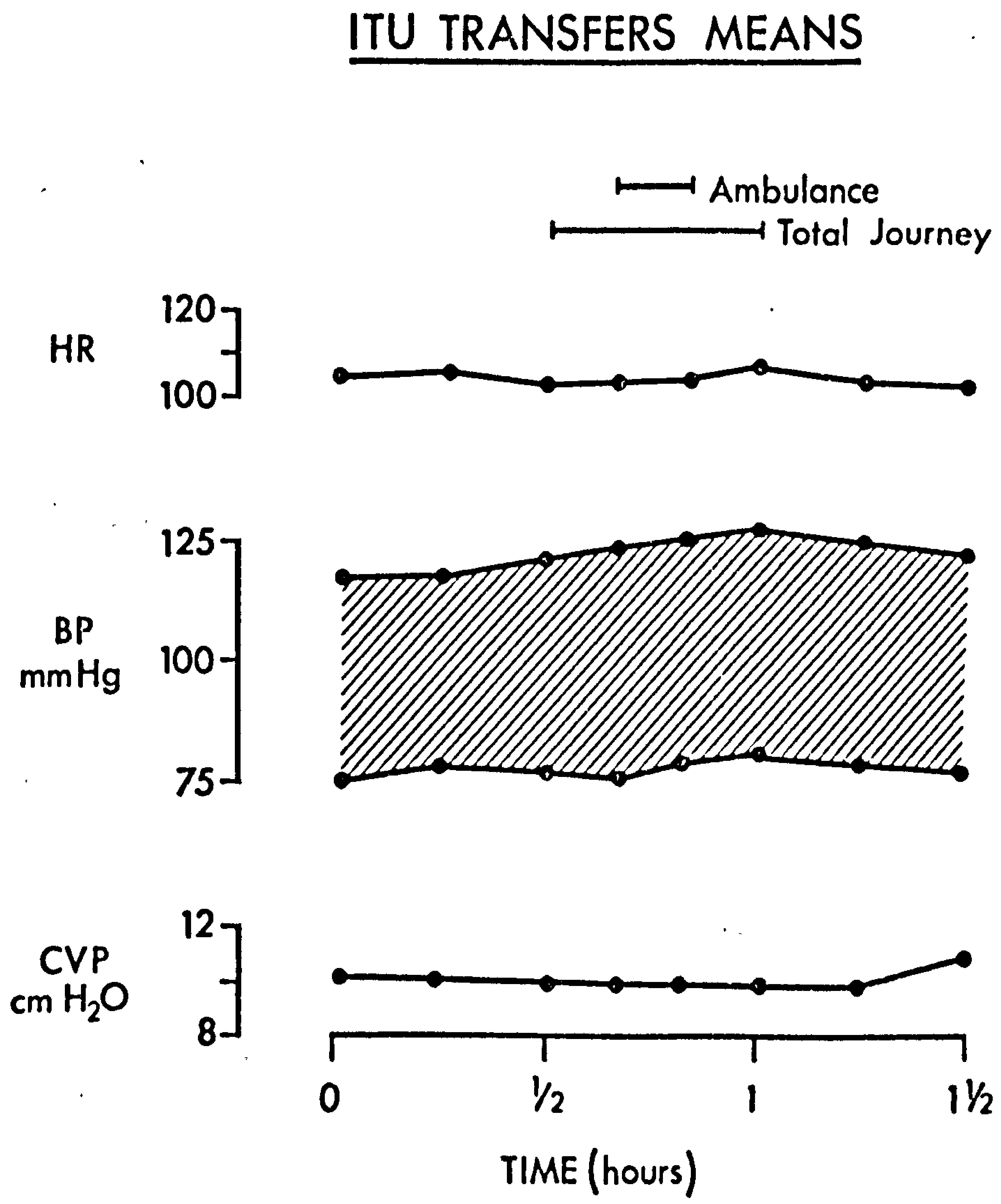

FIGURE 6. Study IIa: mean cardiovascular data of 20 critically ill patients transferred by ambulance.

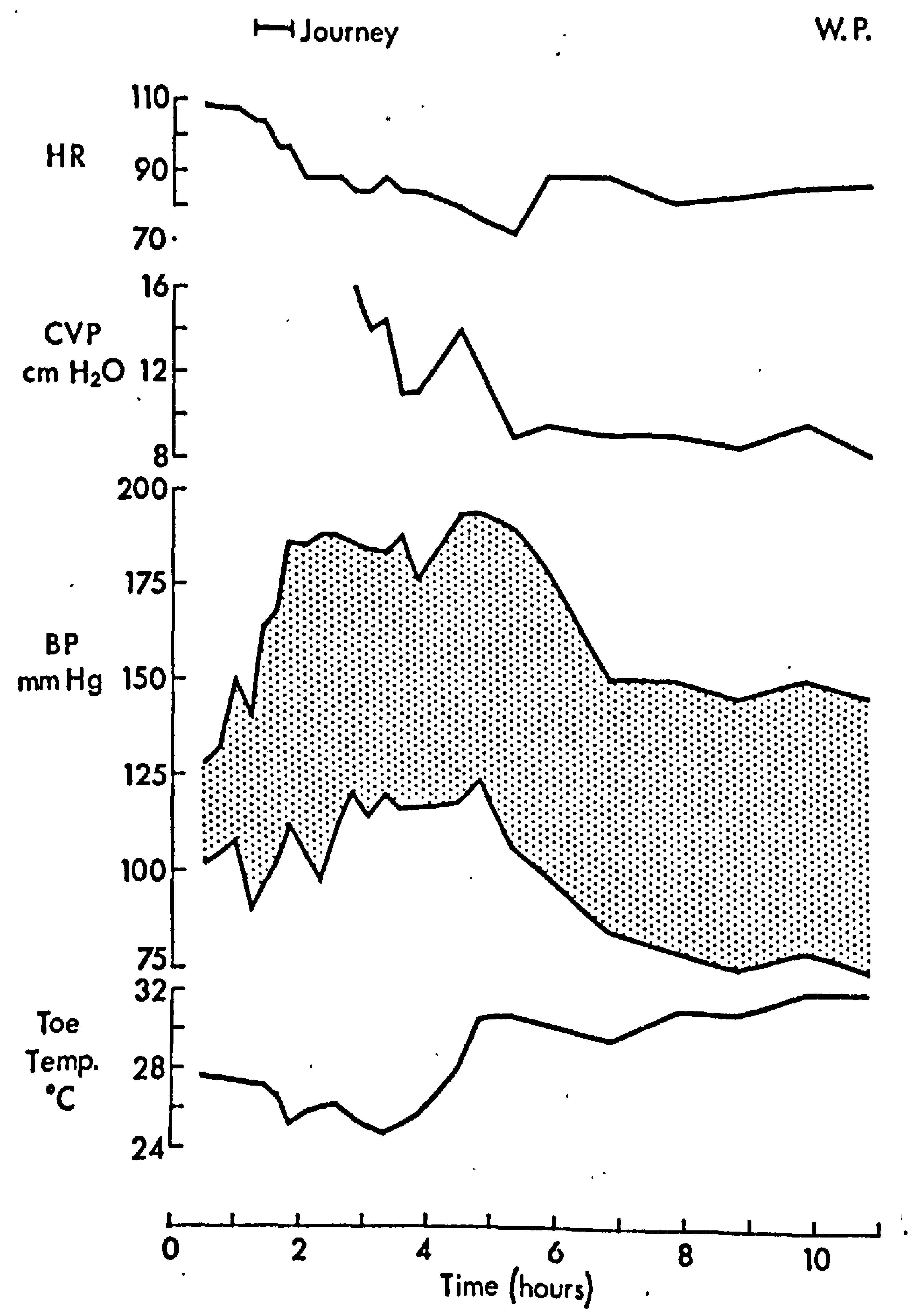

FIGURE 7. Study IIa: one example of a hypertensive response apparently due to over-transfusion.

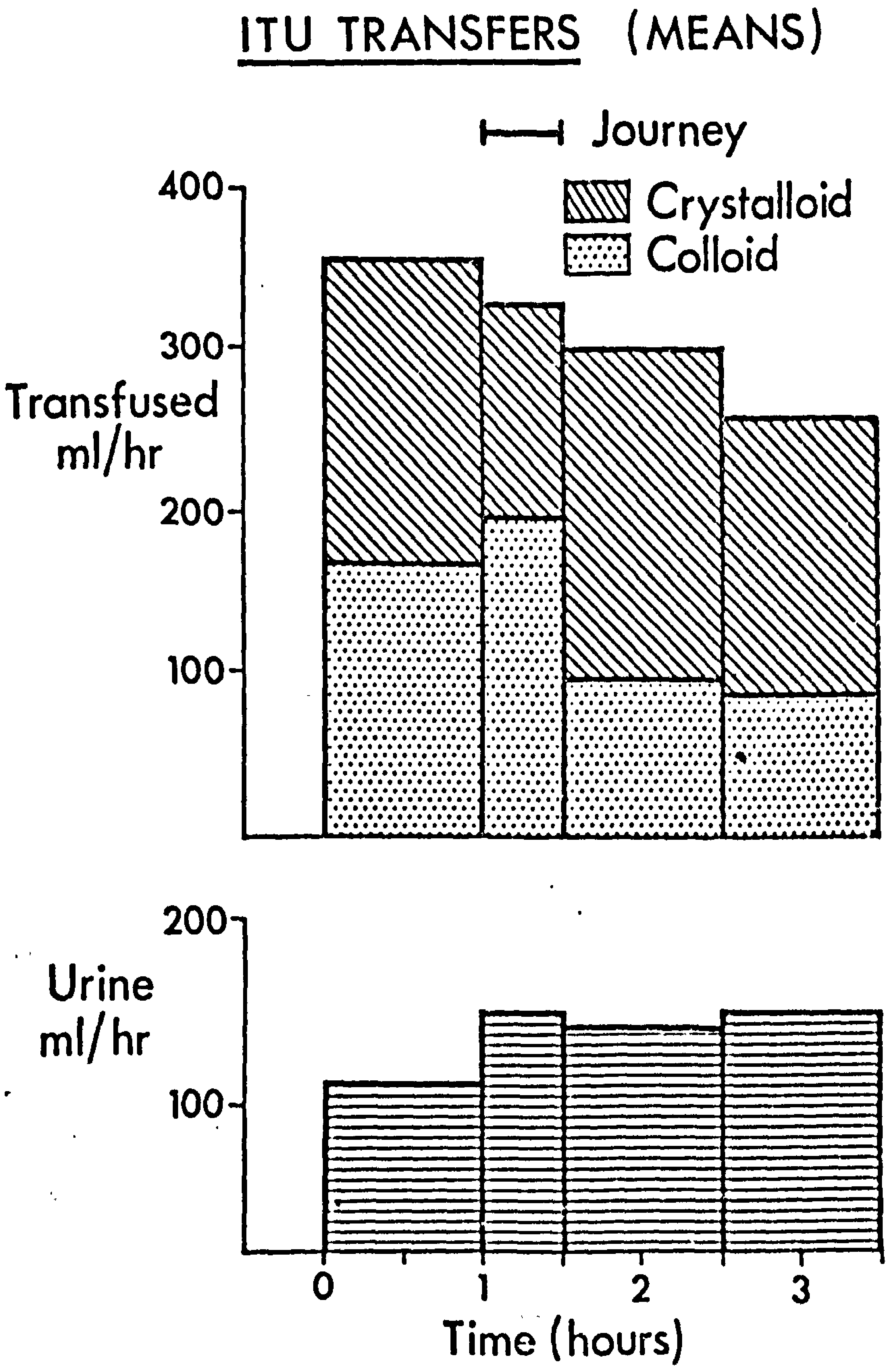

FIGURE 8. Study IIa: mean fluid balance of critically ill patients transferred by ambulance.

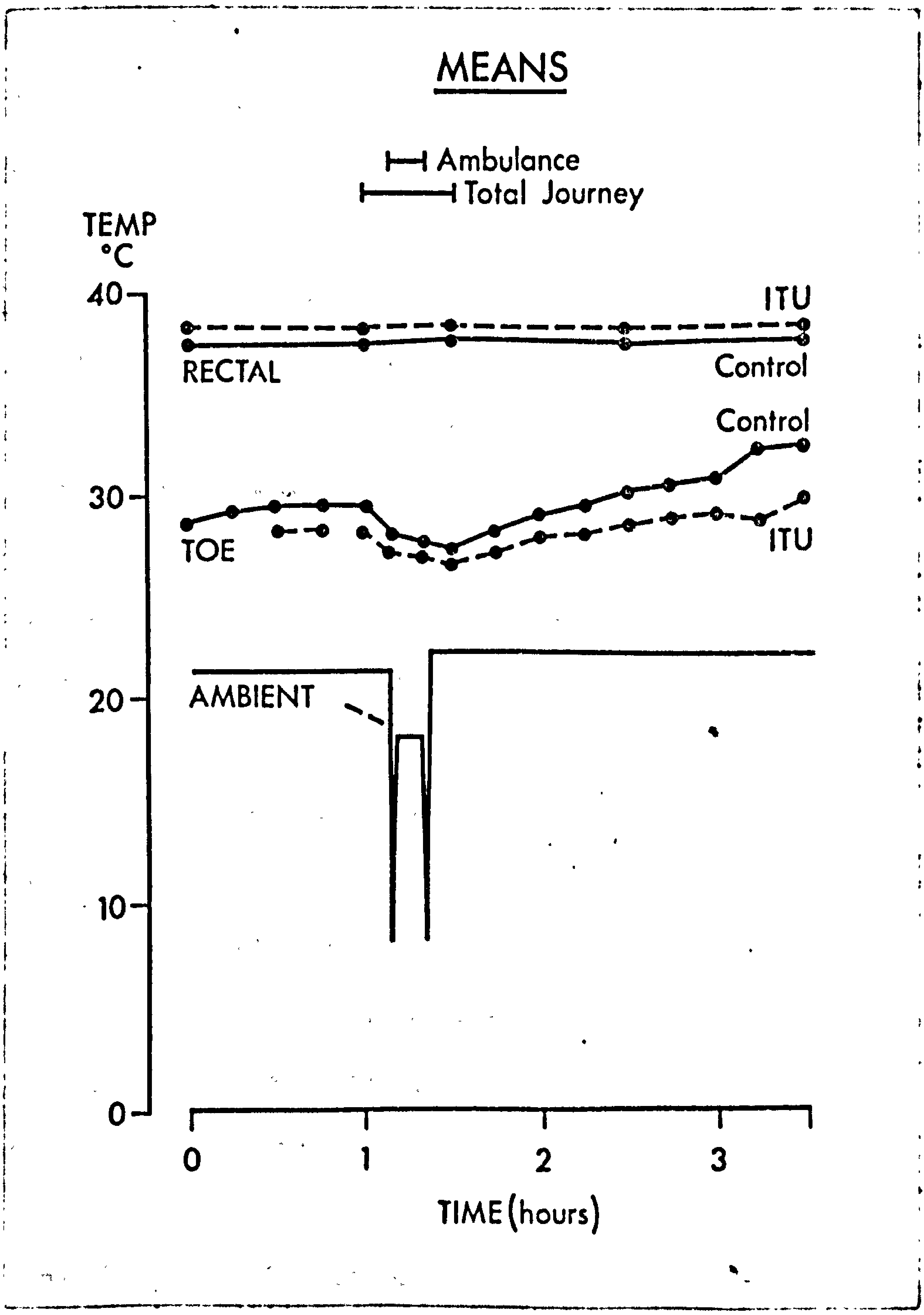

FIGURE 9. Study IIa: mean rectal and toe temperature of 20 critically ill ITU patients (ITU) and 20 convalescent surgical patients (CONTROL) transferred by ambulance.

Discussion

Compared with the retrospective review (Study Ic), there was a marked reduction in the number of patients who became hypertensive and none became severely hypotensive. Three of the four cases of delayed hypotension were related to the commencement of IPPV shortly after the patient reached the ITU. The consistent timing is probably due to the 1 - 1½ hours required to assess the patient on arrival at the ITU, reach decisions and implement any changes in therapy. The incidence of blood gas changes was reduced from 46% in the retrospective review to 15%. The three remaining instances of altered blood gases were related to changes in oxygen therapy or the administration of narcotics. This confirms the difficulty of assessing and maintaining inspired oxygen and ventilatory requirements during transfer. The fit appeared to be a direct consequence of ambulance movement: it was rapidly controlled, but might have been prevented by increased sedation before transfer, as shown by Poisvert[44]. The slight fall in toe temperature suggests mild peripheral vasoconstriction[83], but the clinical significance of this observation is difficult to ascertain when ambient temperature is changing. All these effects, although potentially harmful, recovered either spontaneously or promptly in response to treatment.

Altogether, the 20 critically ill patients in the prospective study (IIa) showed less frequent and less serious effects of the journey than those seen in the retrospective review (Ic). Most of the remaining effects could be accounted for by changes in treatment during the journey or after arrival at the ITU: evidence for direct stress effects of the ambulance ride itself was minimal.

Several changes in procedure for the transfer of critically ill patients were introduced at the outset of the prospective study. These included careful resuscitation prior to transfer, continuing medical care during the journey and a slow, gentle ride. The relative importance of each of these factors is uncertain, but it is clear that their combined effect prevented the occurrence of serious complications in this group of critically ill patients.

IIb : CLINICAL MONITORING OF CONVALESCENT SURGICAL PATIENTS

The aim of this study was to provide a control group of less ill patients undergoing ambulance transfer similar to that in Study IIa.

Patients and methods

20 surgical patients were transferred 2 - 4 days after emergency admission, once they had recovered from any acute illness or emergency surgery and were ready for convalescence or elective investigation. All were fully conscious, breathing air spontaneously and in cardiovascular stability. Only three were receiving intravenous fluids. They were studied over the same two mile transfer (Western Infirmary to Gartnavel) as 15 of the patients in Study IIa.

Non-invasive measurements similar to those in Study IIa were made of HR, BP, ECG, RR, rectal and toe temperature. Readings were again taken for one hour before transfer, in the ambulance at the beginning and end of the journey and for two hours thereafter.

Results

There was no clinically significant change in HR, BP, ECG, RR or rectal temperature, individually or mean (Fig. 10). The only change seen was the slight drop in toe temperature (Fig. 9 - p74).

Discussion

The complete stability suggests that such patients are not clinically influenced by a short ambulance journey. The slight fall in toe temperature was exactly comparable to that seen in the ITU transfers and suggests that in both groups slight peripheral vasoconstriction[83] was related to changing ambient temperature rather than an effect of transport.

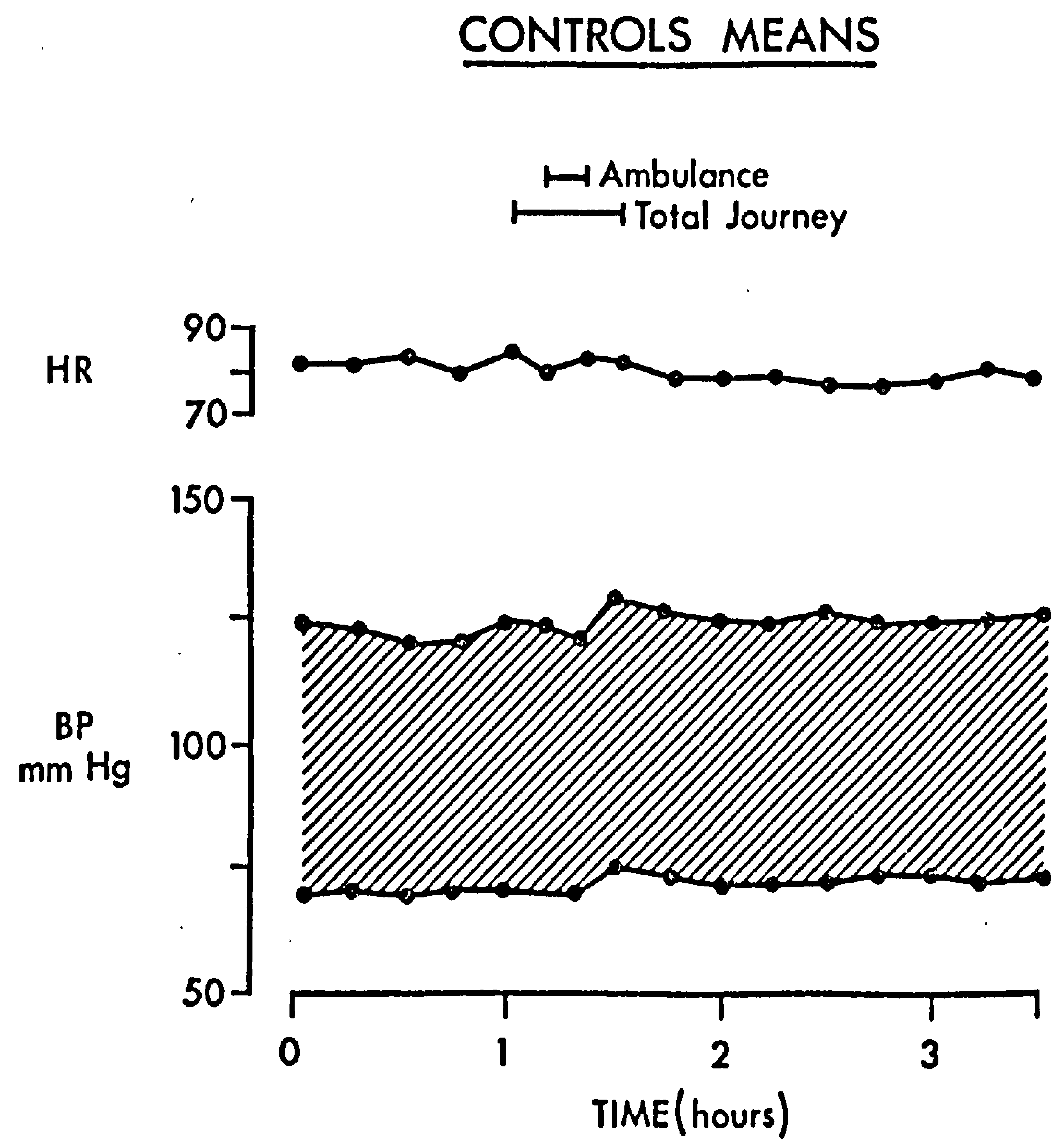

FIGURE 10. Study IIb: mean cardiovascular data of 20 convalescent surgical patients transferred by ambulance.

IIc : ELECTRONIC AND INTRA-ARTERIAL MONITORING OF ITU TRANSFERS

The retrospective review of patients transferred from other hospitals to the ITU (Study Ic) showed an incidence of cardiovascular change comparable to previous studies[39,43]. In addition to hypotension[39,43] and fits[39,44], sustained hypertension, delayed hypotension and increased P_{CO_2} were also noted. Prospective clinical monitoring of 20 similar patients (Study IIa) showed a marked reduction in the changes observed and most of the remaining effects were apparently caused indirectly by changed or inadequate treatment rather than directly by the ambulance ride. Due to the intermittent nature of the clinical observations, any transient changes would not have been detected in these studies.

The present investigation was designed to study the effect of movement and ambulance transport on continuously recorded intra-arterial BP with simultaneous measurement of other physiological variables and an accelerometer record of movement. There is no previous report in the world literature of intra-arterial monitoring in ambulances, neither in healthy subjects nor ill patients.

Patients and methods

18 critically ill patients were studied during ambulance transfer from other hospitals to the ITU of the Western Infirmary. Adequate records were obtained on 13 patients (Table VIII). In two of these patients an ear lobe plethysmograph was tested. The remaining 11 patients with arterial lines form the main part of this study.

A lead I ECG was obtained by three standard chest electrodes (Dracard), the leads being securely taped to the patient to avoid mechanical disturbance. Using a Riley needle and the micro-Seldinger technique[84], a 30 cms FG4 catheter (Portex) was inserted for a distance of 10 cms into the radial artery by either percutaneous puncture or cut-down. The catheter was looped 180° and connected via a three way tap to a semi-conductor strain-gauge transducer (Elcomatic EM750) securely taped to the forearm.

ECG and BP were displayed on a dual-channel oscilloscope (Rigel DM722 with modified time constants) mounted on the foot of the trolley. By a time division multiplexing system both ECG and BP were recorded on one channel of a four channel FM magnetic tape recorder (Tandberg Series 100) slung beneath the trolley and cushionned on foam. Power was supplied from a standard 12 volt lead-acid car battery slung beneath the trolley and recharged after each transfer. For the tape recorder, DC battery voltage was converted to 250 volts AC by a 50 Watt inverter (Vega-Cantley Ltd).

Tri-axially arranged accelerometers (Kulite GY/125/10) were securely taped over the patient's forearm and an inclinometer (Electrolevel ELH 50) mounted on the trolley. These four signals were multiplexed and recorded on the second channel of the tape recorder. Conventional axes used were (in the supine position): X - vertical (up positive); Y - transverse (right positive); Z - longitudinal (head positive). All patients travelled head first. Voice comments were recorded on the third channel.

A 7 in., 2400 foot tape gave two hours recording. A demultiplexing unit on the trolley allowed the information to be transferred later from tape to a standard eight channel ink-jet recorder (Mingograph 81). Calibration at the start and end of each recording showed no drifting. Artefact in the ambulance was minimal (Fig. 11). HR and end-expiratory BP at five minute or, if necessary, lesser intervals were used to construct a time-condensed chart to show general trends (Fig. 12).

CVP, RR, arterial blood gases, urine output, rectal and toe temperatures were measured before and after the journey by standard techniques (Study IIa).

An ear-lobe plethysmograph was tested in two patients (Patients 12 and 13) as an alternative to the arterial line, but was found to fluctuate widely with minor changes in position and bore no relationship to BP recorded by sphygmomanometer.

The ITU flying squad took resuscitation and monitoring equipment to the patient's bedside in the referring hospital. Transfer did not begin till the patients were resuscitated and their clinical condition allowed to stabilise. If on IPPV they were changed to a Harlow ventilator and the previous pattern of ventilation matched as closely as possible. Monitoring equipment was set up and 20 minutes base-line obtained in bed before any movement. The patients were then lifted by hand from bed to the transfer trolley. The patients remained undisturbed on this trolley throughout the journey. Tilting was avoided when lifting the trolley in and out of the ambulance. All aspects of treatment - IPPV, oxygen supply, intravenous infusion, drugs, etc. - were maintained as far as possible without interuption throughout the transfer. On arrival at the ITU, patients were again lifted by hand from the trolley to the ITU bed. A continuous recording was made for 20 minutes base-line in bed before any movement, throughout all phases of the journey and for 20 minutes after cessation of movement in the ITU bed. If patients were on IPPV, recordings were made during the change from the referring hospital ventilator to the Harlow at the start of the 20 minutes base-line, and from the Harlow to a Cape ventilator at the end of the final 20 minutes in the ITU bed. Mean distance transferred was ten miles (2 - 17 miles). Mean duration of the ambulance ride was 29 minutes (10 - 52 minutes) and mean total duration of movement from bed to bed was 61 minutes (32 - 90 minutes).

Results

The clinical conditions of the 13 patients and the main effects of transport are summarised in Table VIII. The over-all cardiovascular stability which was a striking feature of the entire study is illustrated in Figure 11.

Patients 4 and 5 developed sustained hypertension (Fig. 12), in each case beginning before movement started and apparently related to inadequate IPPV with a Harlow ventilator and a rising arterial Pco_2. Patient 6, on an isoprenaline infusion, had a gradual fall in BP from

100/65 to 85/50 mm Hg over the period of observation with an accompanying fall in urine output. The timing suggests that this may again have been related to changed IPPV. Arterial Po_2 fell over the period of transfer from 74 - 50 mm Hg on 100% oxygen, and the cardiovascular state improved when a Cape ventilator was used in ITU. All these sustained phenomena occurred early in the series before experience was gained of the Harlow ventilator. Recent patients transferred on IPPV have shown no such changes ($P<0.02$, Fisher's exact test).

A further seven patients showed episodes of transient hypertension: thus a total of nine out of 11 patients had a rise in BP at some stage of the journey. In patient 7, transient hypertension was particularly marked with repeated rises up to 200/115 mm Hg (Figs. 13 & 14). The frequency of transient hypertension (Fig. 15) progressively increased over the period of observation ($P<0.025$, χ^2 test), but was significantly more frequent during movement to and from the ambulance ($P < 0.0005$, χ^2 test). It was especially common when lifting the patient on and off the trolley and when lifting the trolley in and out of the ambulance (Fig. 14).

Only four episodes of transient hypotension each lasting 20 - 90 seconds were observed in two patients (Patients 6 and 10). Three of the four episodes occurred on lifting the patient on or off the trolley (Fig. 16) and only one during the ambulance ride. One of these two patients (Patient 6) was the most ill of the entire group, on an isoprenaline infusion and dying 28 hours after transfer, but the other (Patient 10) was one of the least acutely ill, with a stable cardiovascular state and breathing spontaneously.

Eight of the 13 patients (Table VIII) had ventricular extrasystoles at some stage of the recordings. In several of these patients there was a noticeable increase in frequency during movement, particularly during the moves to and from the ambulance (Figs. 17 & 18). In most patients the extrasystoles were probably of no clinical significence, but in Patient 11 repeated runs of 4 - 6 consecutive ventricular extrasystoles occurred till they were controlled by intravenous lignocaine in the ITU. The increased frequencies of extrasystoles during movement to and from the ambulance (Fig. 18) were highly significant ($P < 0.0005, \chi^2$ test). Control journeys on six healthy, young adult males showed no extrasystoles.

There were no cases of sudden collapse, arrhythmia, acute respiratory insufficiency or fits during the journey. No patient died during or within 24 hours of the journey. All the reported effects rapidly reverted to normal either spontaneously or with adjustment of treatment, and in no case did the journey appear to contribute to later death. The effects seen in the 11 patients with arterial lines are summarised in Table IX.

TABLE VIII

Critically ill patients transferred by ambulance from other hospitals to a central ITU

Patient	Sex	Age	Presenting problem	Distance transferred (miles)	Treatment during transfer	EFFECTS OF JOURNEY	
						Cardiovascular	Respiratory
1	M	54	Post cardiac arrest Brain death	17	IPPV	Transient hypertension Solitary extrasystole	-
2	F	50	Haemorrhagic shock Ruptured spleen	17	-	Transient hypertension Extrasystoles	-
3	F	61	Septic shock GI anastomotic leak	2	-	Transient hypertension Extrasystoles	-
4	F	17	Haemorrhagic shock Stab wound loin	7.5	IPPV	Sustained hypertension	Inadequate ventilation increased P_{CO_2}
5	M	54	Crushed chest Multiple fractures	17	IPPV	Sustained hypertension Extrasystoles	"fighting ventilator" increased P_{CO_2}
6	M	62	Septic shock GI anastomotic leak	17	IPPV isoprenaline	Progressive mild hypotension Solitary extrasystole	decreased P_{O_2}
7	M	50	Septic shock GI anastomotic leak	2	IPPV	Marked transient hypertension	-
8	F	50	Post-op. respiratory failure	2	IPPV	Transient hypertension	-
9	M	30	Respiratory failure Chronic chest disease	2	IPPV	Transient hypertension Extrasystoles	-
10	F	69	Metabolic failure Biliary fistula	17	-	Transient hypotension	-
11	F	52	Chronic resp. failure Post-cardiac arrest	4	IPPV	Transient hypertension Extrasystoles (runs)	-
PLETHYSMOGRAPH							
12	F	75	C5/6 dislocation quadriplegia	9	Traction	-	-
13	M	65	Septic shock Perforated Crohn's disease	2	-	Extrasystoles	-

TABLE IX

Intra-arterial monitoring of 11 ITU patients during ambulance transfer

		Number of patients
Sustained effects:		
Hypertension	increased Pco_2	2
BP 100/65→85/50	decreased Po_2	1
Transient effects:		
Repeated hypertension		7
Occasional hypotension		2
Ventricular extrasystoles		7

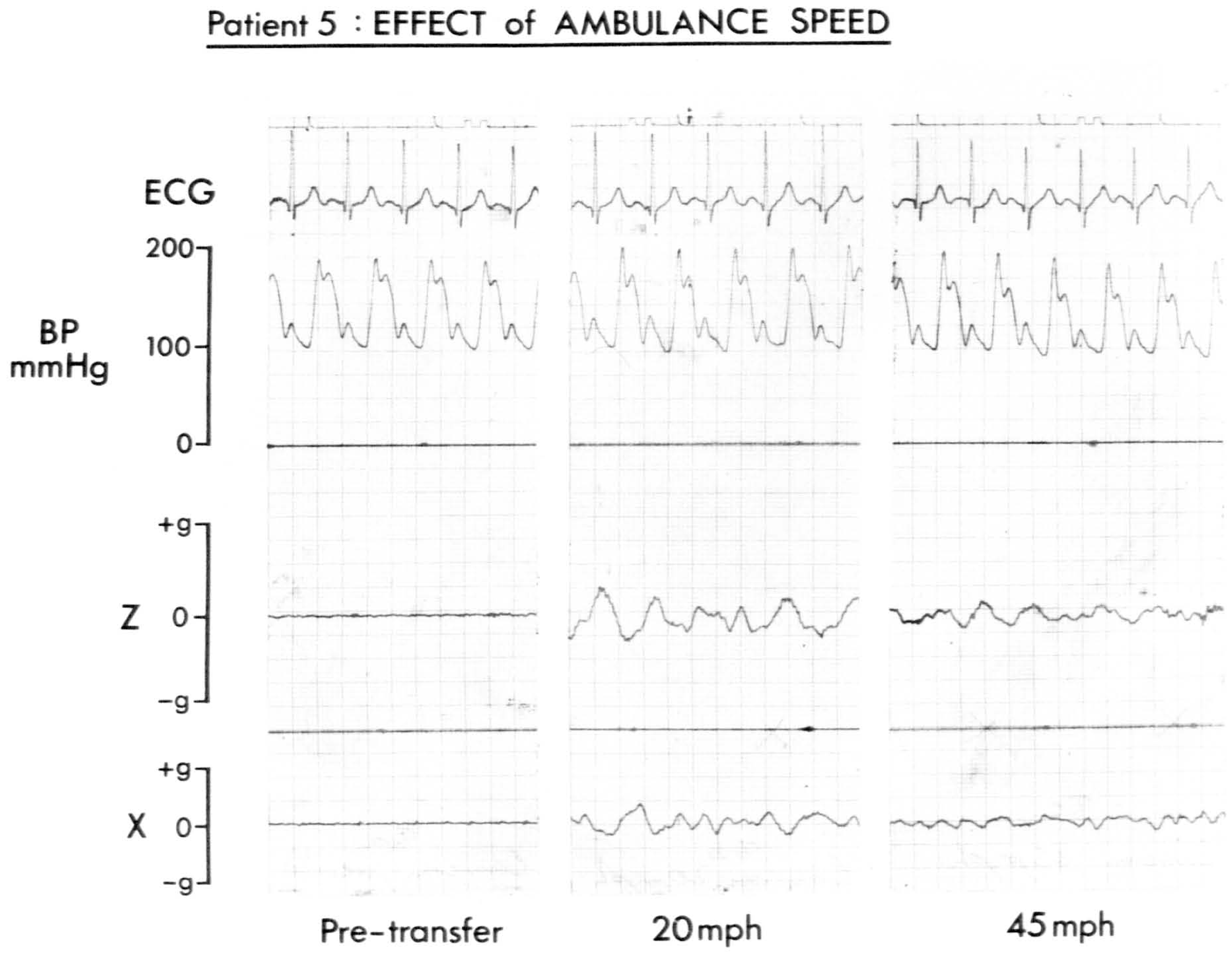

FIGURE 11. Study IIc: Patient 5 - showing the cardiovascular stability which was a striking feature of the entire study. Note also the lack of artefact.

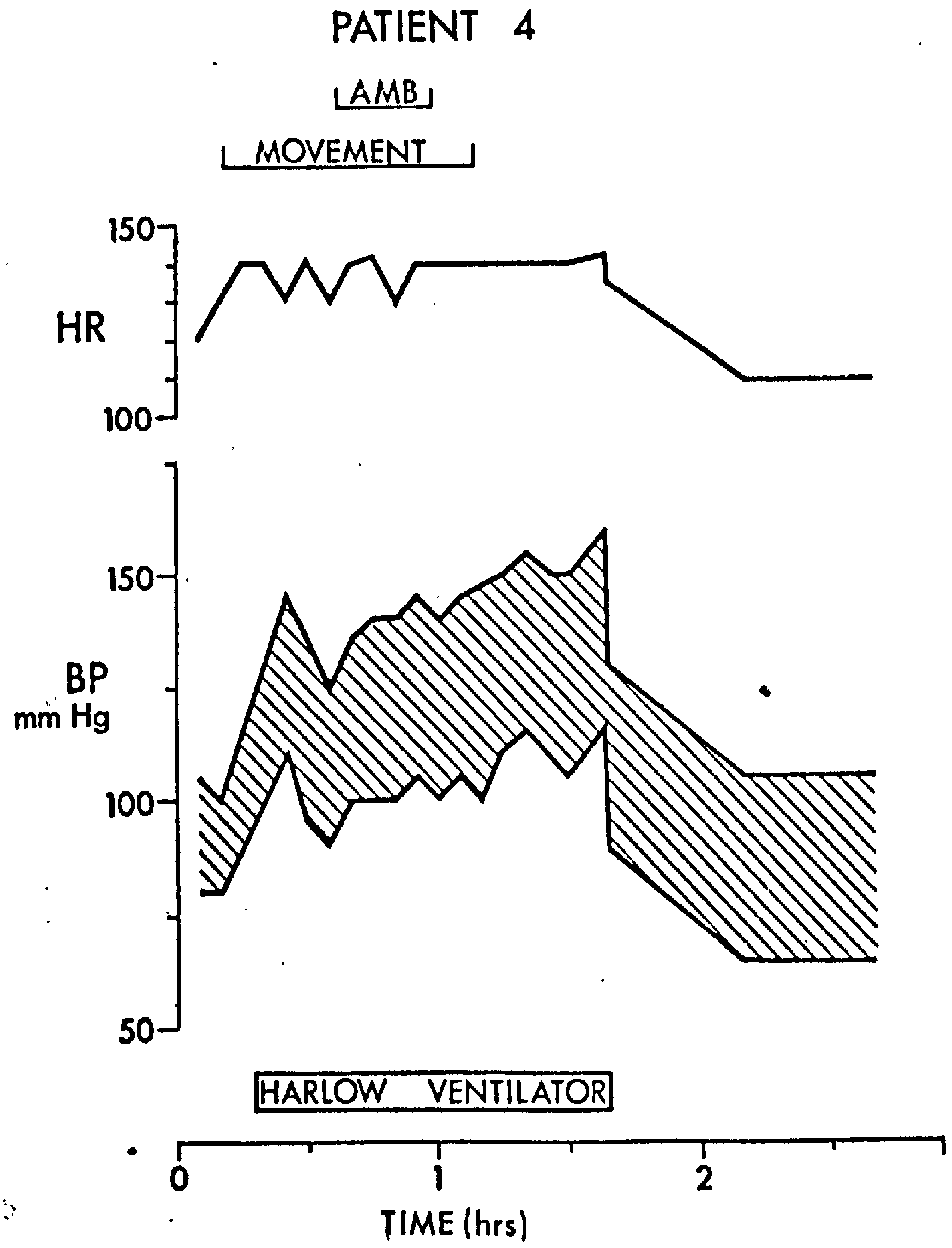

FIGURE 12. Study IIc: Patient 4 - the entire recording showing sustained hypertension apparently caused by inadequate IPPV on the Harlow ventilator.

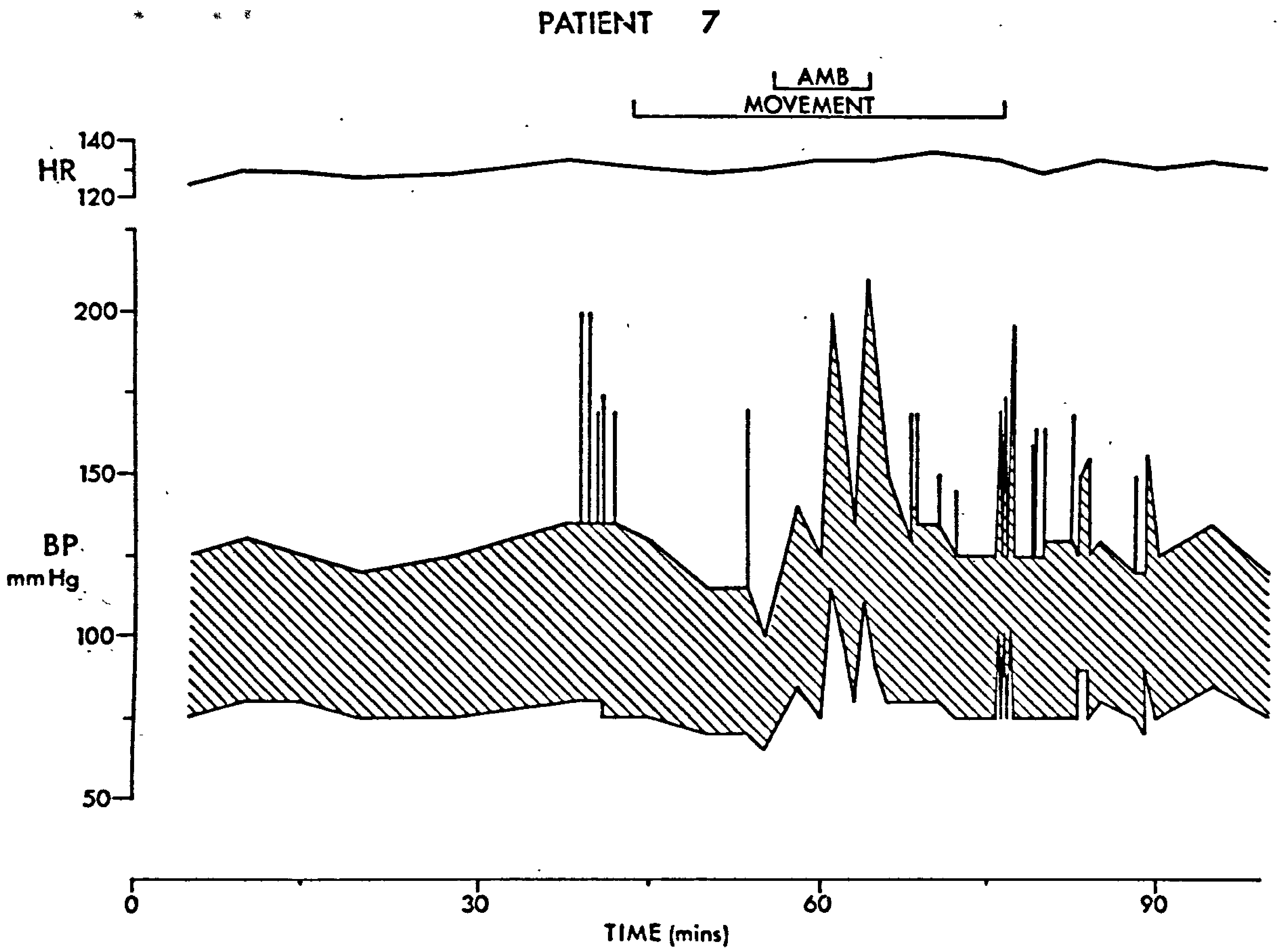

FIGURE 13. Study IIc: Patient 7 - the entire recording showing marked and repeated transient hypertension.

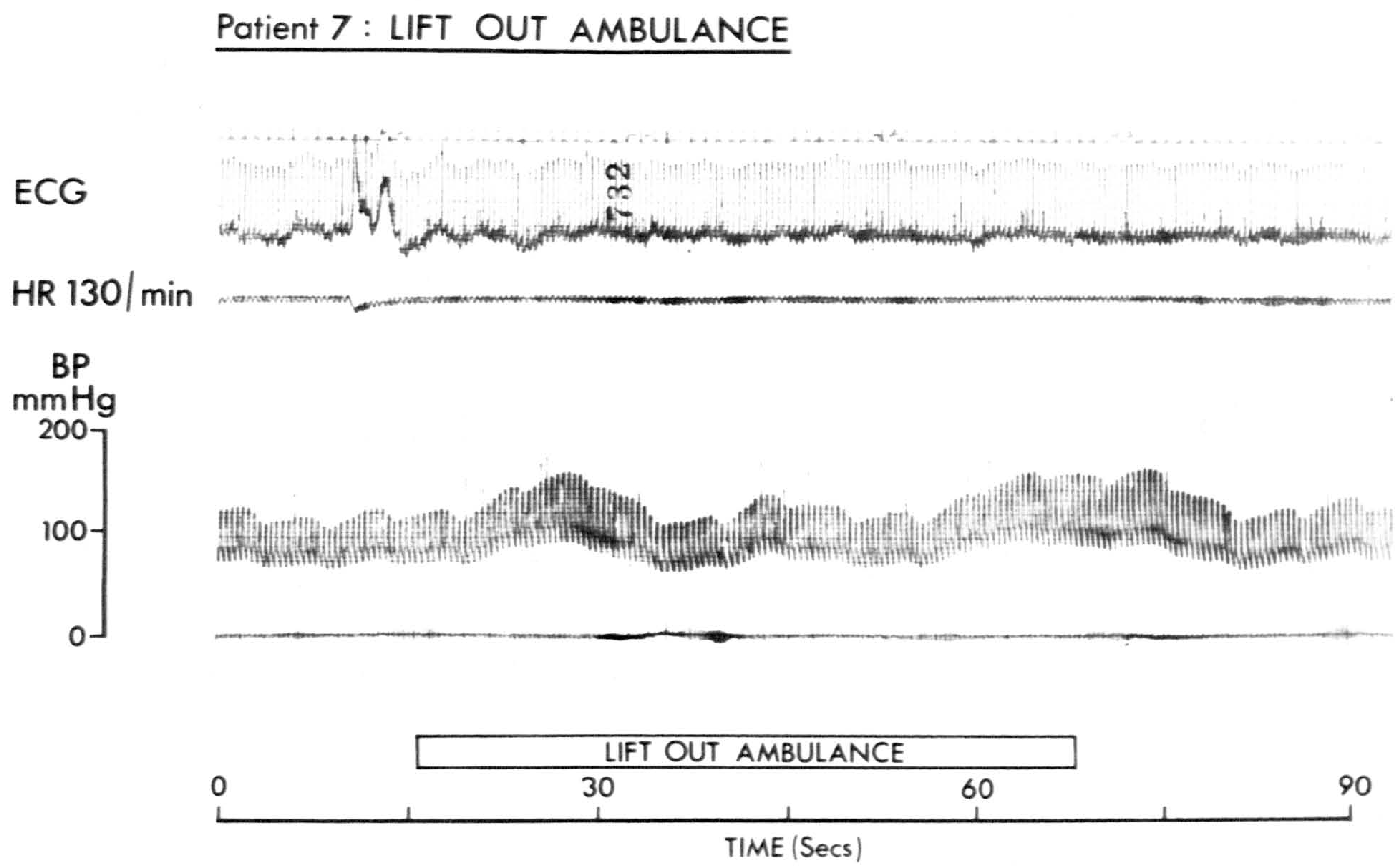

FIGURE 14. Study IIc: Patient 7 - an example of the recording showing transient hypertension on lifting the patient out of the ambulance.

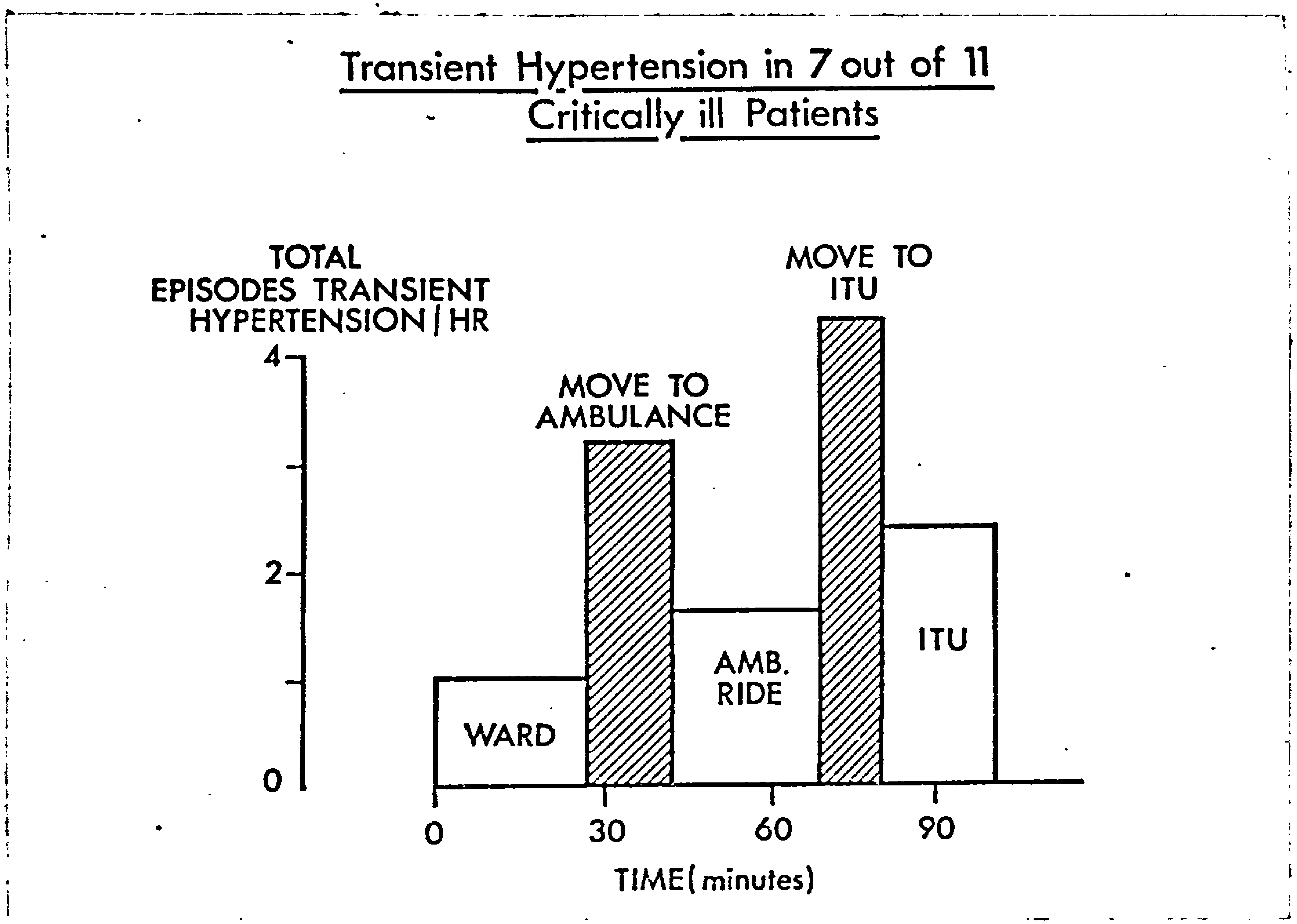

FIGURE 15. Study IIc: total episodes of transient hypertension occurring in seven out of 11 patients.

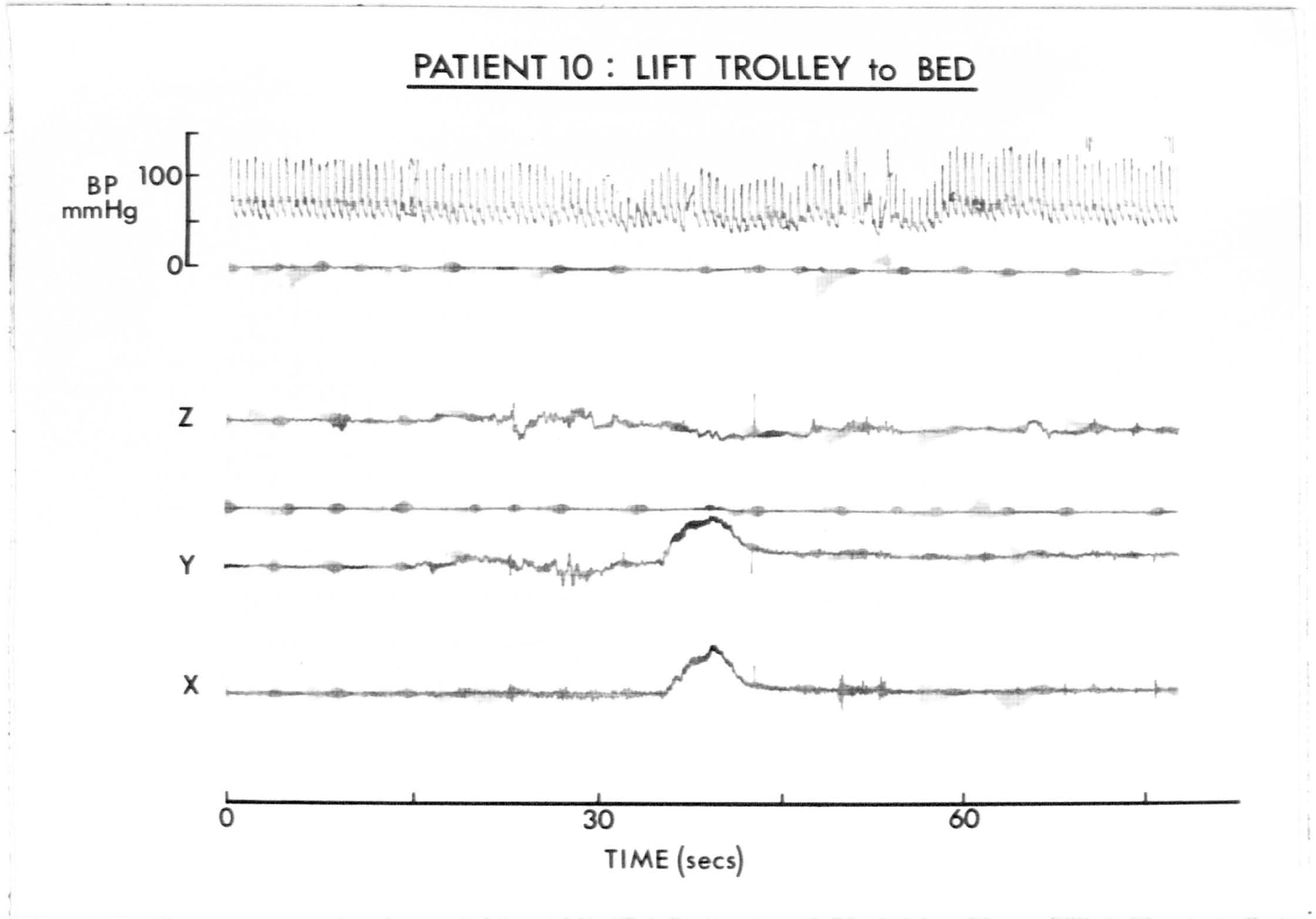

FIGURE 16. Study IIc: Patient 10 - transient hypotension on lifting the patient from trolley to bed at the end of the journey.

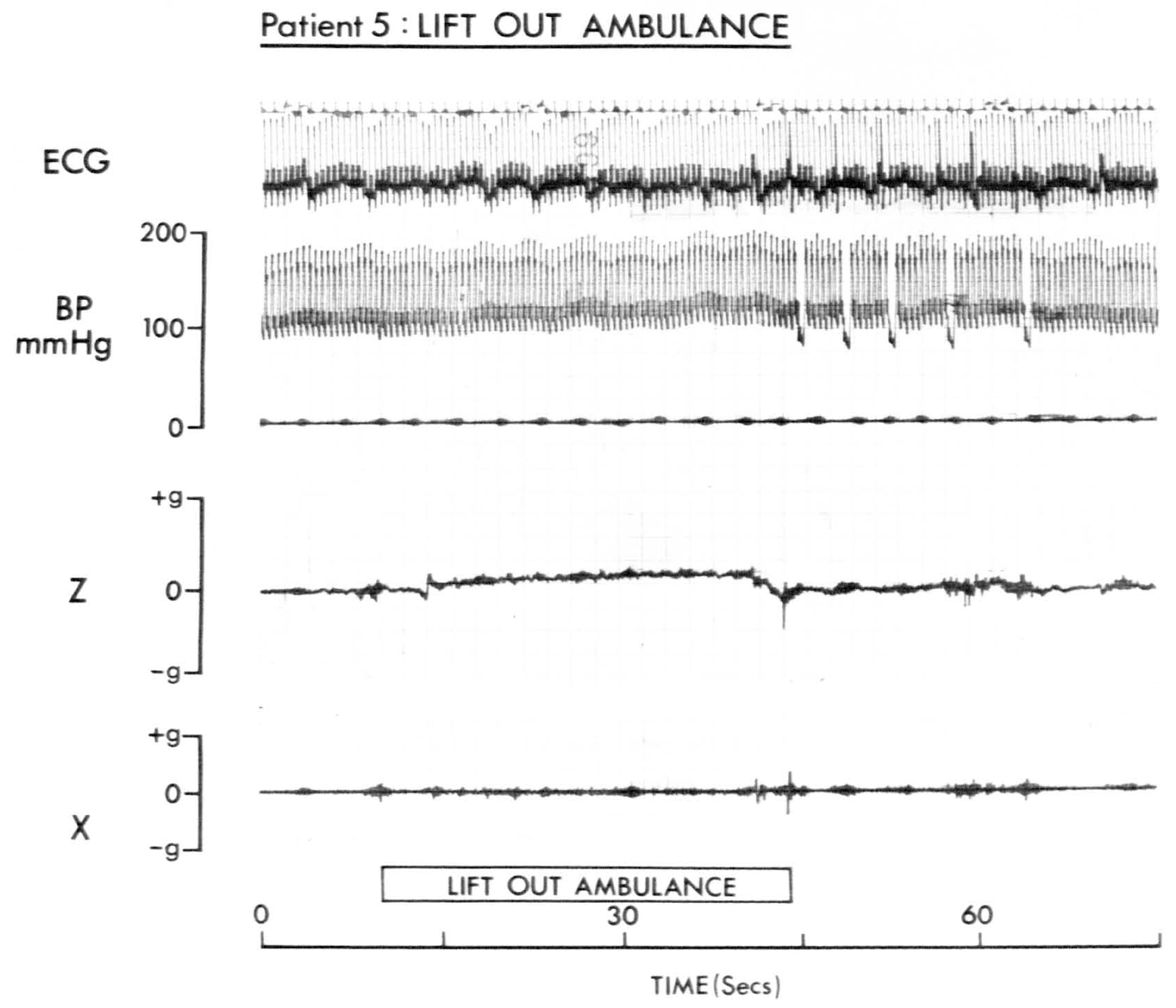

FIGURE 17. Study IIc: Patient 5 - extrasystoles occurring on lifting the trolley out of the ambulance.

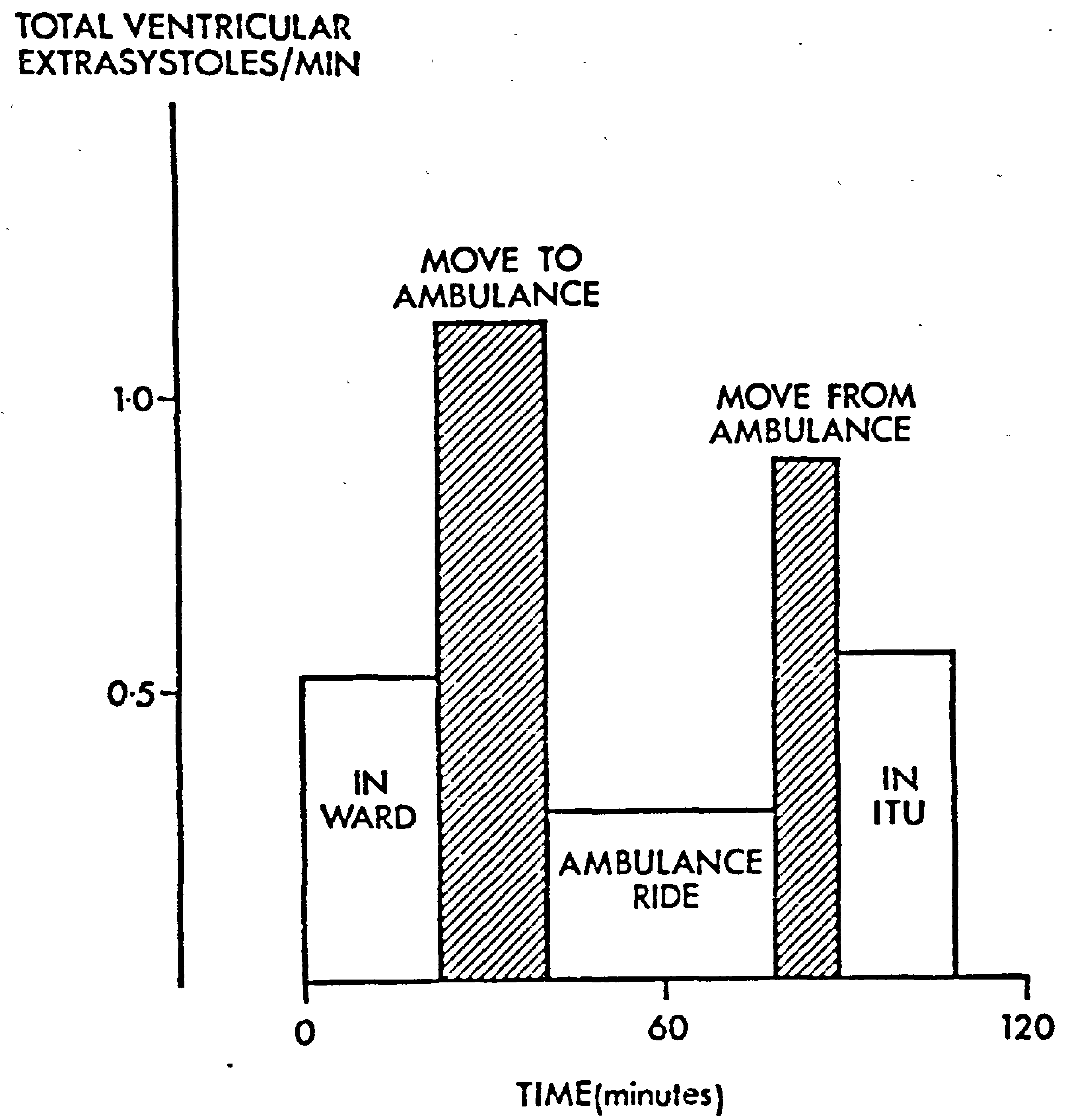

FIGURE 18. Study IIc: total ventricular extrasystoles occurring in eight out of 13 patients.

Discussion

The effects of an ambulance journey may be either direct or indirect[21]. All the sustained effects observed, comparable to those noted in the retrospective study (Ic), have been caused indirectly. Sustained hypertension has been caused by changed IPPV (Patients 4 & 5) or over-transfusion (Study IIa). With maintenance of treatment during the journey sustained hypotension of the severity seen in the retrospective review (i.e. a fall of more than 40 mm Hg to under 80 mm Hg) has not occurred in 38 patients. Delayed hypotension was related to changed treatment after arrival at the ITU (Study IIa). Blood gas changes were due to changes in IPPV (Patients 4, 5 & 6) or inspired oxygen (Study IIa) or to narcotics (Study IIa).

Direct effects of the journey appeared to be transient and to settle spontaneously when travel was over[39]. In this study, transient hypertension occurred in seven out of 11 patients. Hypertension may occur in response to over-transfusion, inadequate IPPV and increased Pco_2, "fighting the ventilator", Ambu bag, endotracheal toilet, the ambulance ride, sudden jolting of the ambulance, lifting in or out the ambulance or lifting from trolley to bed or vice versa. Surprisingly, previous literature makes no mention of hypertension in ambulance transport, especially as it is a common response to stress in other situations. Transient hypotension was found to be rare: only four minor episodes in 20 hours recording in critically ill patients. The emphasis on hypotension in previous reports[21,24,39,40] may have been exaggerated. Alternatively, it may have been prevented in the present studies by meticulous attention to maintaining treatment throughout transfer. The increased frequency of extrasystoles has been suspected previously[36].

The high incidence of transient effects during the move to and from the ambulance was striking. Transient hypertension was common, though generally not as severe as that observed during the ambulance ride. Three out of four episodes of transient hypotension occurred during such movement and only one during the ambulance ride. Ventricular extrasystoles were significantly more frequent during movement to and from the ambulance but not during the ambulance ride. It appears that movement to and from the ambulance may be at least as hazardous as the actual ambulance ride. Previous emphasis on the ambulance ride may have been misplaced.

The clinical significance of these transient effects is uncertain. Hypertension could potentially precipitate renewed haemorrhage, cause deterioration in certain intra-cerebral states or result in decompensation if cardiovascular reserve is impaired. Hypotension could cause further tissue anoxia endangering cerebral, myocardial or renal function. Occasional extrasystoles are of little significance[85], but if more frequent (as in Patient 11), may lead to more significant arrhythmias. However, although renewed haemorrhage[21,24], cardiovascular collapse[39,40], fits[39,44] and arrhythmias[30,45] have all been reported during transport, none of the transient phenomena reported here was observed to lead to clinical harm. Although the incidence of transient phenomena during movement was significantly higher than during the pre-movement base-line period, critically ill patients are probably liable to such fluctuations in response to minor stimuli.

Continuous intra-arterial monitoring of critically ill patients during ambulance transport has demonstrated phenomena which were not previously suspected clinically. No clinical harm was observed to result and over-emphasis of their clinical significance should be avoided. This new information has not altered the basic safety of ambulance transport observed in these studies. Knowledge of the occurrence of these transient phenomena may, however, permit further measures to be taken to prevent harm developing. A stretcher might be more gentle for lifting patients on and off the trolley. It is possible that heavier sedation might limit transient hypertension, while lignocaine could be used to control extrasystoles. Greater attention should be given to the move to and from the ambulance.

IId : ORGANISATION AND FUNCTION OF AN AREA ITU FLYING SQUAD

While obstetric[3], accident[4] and coronary[5] flying squads are now common, there is no previous report in the English literature of a flying squad organised specifically for secondary evacuation of critically ill patients.

Three groups of patients contributed to the development of the ITU flying squad (Table X). The retrospective review of 46 patients transferred to the ITU of the Western Infirmary from 1968 - 1973 (before the introduction of the flying squad) provided a baseline (Study Ic). In Study IIa 20 patients were transferred by the flying squad with simple clinical monitoring. In Study IIc 18 patients were transferred by the flying squad, 11 with continuous intra-arterial monitoring.

Development of the ITU flying squad

From 1968 to 1973 no special facilities were available for patients transferred from other hospitals to the ITU. Nursing, resident or anaesthetic staff from the referring hospital accompanied the patient in an ordinary ambulance. Any special equipment required had to be improvised on each occasion.

With the increased number of referrals after Gartnavel opened, transfers became the responsibility of the Shock Team. On request, one or two medical members of the team travelled to the referring hospital, taking a portable, battery-operated ECG machine (Transrite II) and a case containing basic resuscitation and monitoring equipment. (The contents of this case gradually evolved into those described later). A stripped down Boyle's machine was used to provide oxygen and to power a simple Cyclator ventilator. Simple resuscitation and clinical monitoring was commenced and the patient accompanied during transfer in an ordinary ambulance. The results of transferring 20 patients in Study IIa (July 1973 to March 1974) justified setting up a fully equipped ITU flying squad.

Study IIc began in September 1974 with the introduction of additional monitoring and resuscitation equipment and the scheme was extended to include two large district hospitals 7.5 and 17 miles distant. The ITU was the communication centre and on receipt of a "shock call" two medical members of the Shock Team and one technician travelled to Gartnavel, where the ITU ambulance was garaged. A hospital porter (or occasionally a member of the flying squad) drove the ambulance and flying squad to the referring hospital. The transfer trolley (Fig. 19) was taken to the patient's bedside and resuscitation and monitoring begun. After stabilisation for one to six hours the patient was transferred with continuous treatment and monitoring until settled in the ITU. The flying squad was also used for occasional critically ill patients transferred from the Western Infirmary or Gartnavel to specialised units elsewhere in the City of Glasgow.

Equipment (Study IIc)

A five year old, standard BMC ambulance was kindly supplied by the Scottish Ambulance Service, the interior stripped and clamps fitted to secure a special trolley. Full resuscitation and monitoring equipment was mounted on the self-contained trolley (Fig. 19).

The oxygen supply was taken via a Schreider valve from a 24 cubic foot cylinder mounted on the end of the trolley. A 12 cubic foot reserve cylinder was carried on the trolley and in the ambulance a 48 cubic foot wall-mounted cylinder was used. The oxygen powered a Harlow ventilator and a Venturi suction. Both the oxygen and a 24 cubic foot cylinder of nitrous oxide mounted on the end of the trolley were also connected to standard anaesthetic flow-meters at the head of the trolley. Any mixture of oxygen and nitrous oxide could be supplied to a face-mask, an endo-tracheal tube or an Ambu bag. Alternatively, gas from the flow-meters could be entrained by the Harlow ventilator, allowing IPPV with 40 - 100% oxygen or up to 60% nitrous oxide. An Ambu bag was carried on the trolley for emergency use.

Defibrillating equipment would be desirable, though with prior resuscitation and continuing medical care during transfer the need for this equipment has not arisen to date. Routine facilities included Fenwal infusion sets to permit fast, controlled intravenous infusion despite the lack of height in the ambulance. As patients sustained a drop in peripheral temperature when exposed to fluctuating ambient temperature in Study IIa, washable nylon sleeping bags with full-length zips were introduced. Drugs and supplementary equipment were carried in a separate foam-padded case and are listed below:-

atropine
thiopentone
suxamethonium
pancuronium
diazepam
sublimase
mannitol
bicarbonate
saline (plastic bags)
isoprenaline
digoxin
frusemide
aminophylline
thymoxamine
ketamine HCL
noradrenaline
adrenaline 1:1000
hydrocortisone
chlorpheniramine
calcium chloride
lignocaine
heparin

laryngoscope, spare battery and bulbs
endotracheal tubes
catheter mounts
connectors
oxygen and anaesthetic masks
suction catheters
Ambu bag (on trolley)
IV and CVP cannulae
CVP infusion set
intra-arterial catheters and Riley needle
cut-down set
sterile surgical gloves
Argyle chest drains and Heidbrink flutter valves
stethoscope
Grant thermistor with rectal and toe leads
KY jelly
ECG electrodes and electrode jelly
sterile swabs, Medi-swabs
syringes and needles
vacuum flask and specimen tubes
tape, bandages, safety pins

The monitoring equipment has already been described in Study IIc.

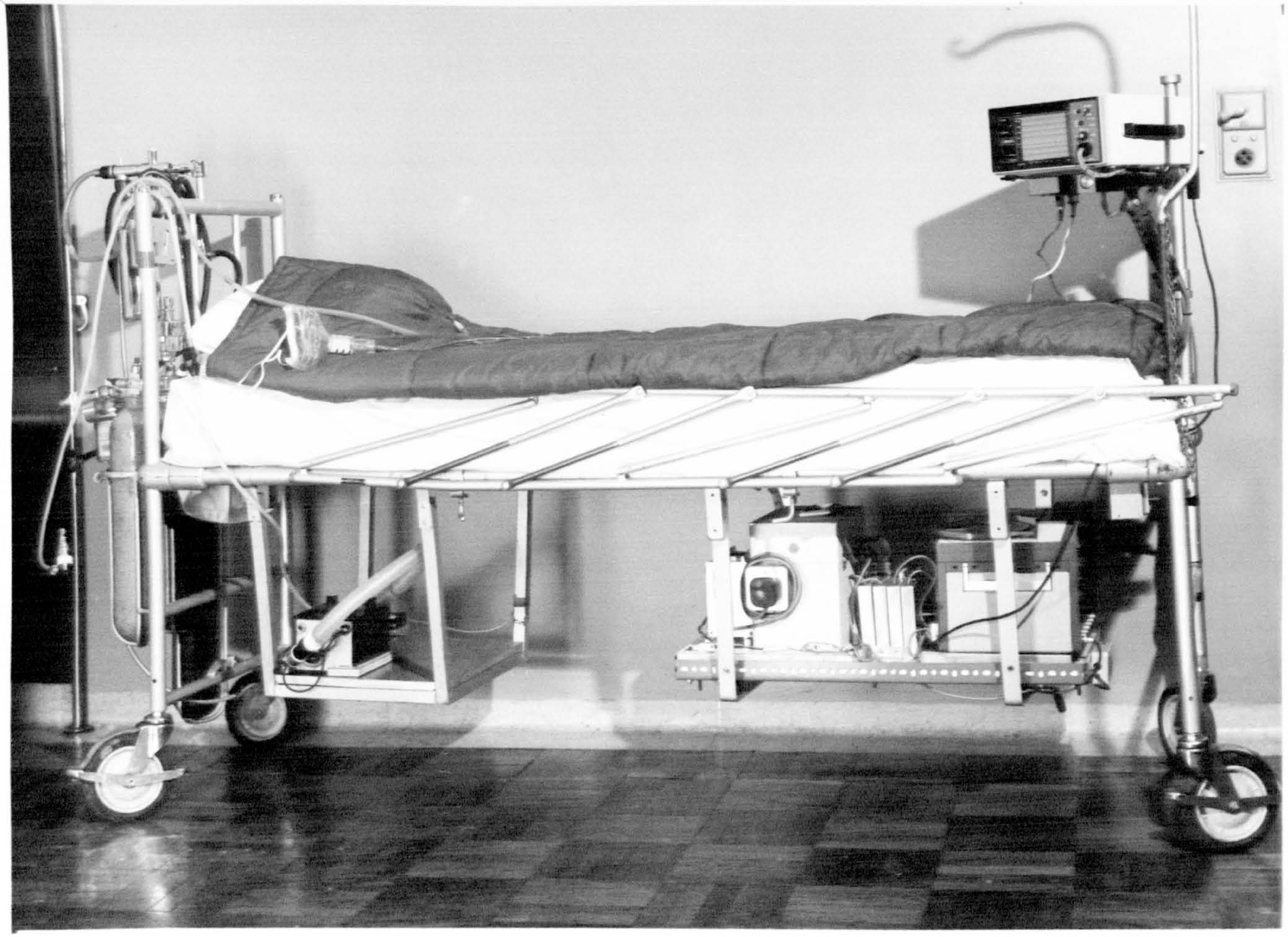

FIGURE 19. Study IId: the special trolley used for resuscitation and monitoring of critically ill patients during ambulance transfer to the ITU.

Logistics

Table X shows the type of patients transferred. Table XI shows the action taken on referrals during the first six months of the expanded service.

TABLE X

Primary problem of patients transferred by the ITU flying squad

Primary problem	Retrospective review	ITU flying squad Study IIa	ITU flying squad Study IIc
cardiac	5	1	2
haemorrhagic shock	4	3	2
septic shock	8	7	5
respiratory failure	10	6	3
chest injury	10	-	2
coma	7	2	1
renal/metabolic failure	2	1	2
quadriplegia	-	-	1
	46	20	18

TABLE XI

Action taken by the ITU flying squad on referrals during the first six months of Study IIc

Referrals:		26
Transferred:		
	with intra-arterial monitoring	9
	without arterial monitoring	6
Not transferred:		
	died before transfer	2
	improved	2
	no bed available	7

Safety of transport

In the retrospective review the incidence of major cardio - vascular change during transfer was comparable to that reported by other authors[39,43]. Since the introduction of the flying squad, Studies IIa and IIc demonstrate the improved safety of ambulance transport under its care. Table XII summarises the clinically significant effects seen in 38 patients transported by the flying squad (Studies IIa and IIc) compared with 46 similar patients reviewed retrospectively (Study Ic). Table XIII demonstrates that most of the remaining effects were still due to changed or inadequate treatment during transfer. Most of these effects occurred early in the prospective series before experience was gained in the use of the ventilatory equipment. The latest eight patients to have been transferred on IPPV have shown no such changes.

Most of the patients in Study IIa were only transported two miles. Longer distance transfers in Study IIc have proved equally safe (Table XIV).

TABLE XII

Clinical effects observed in 38 patients transferred by the ITU flying squad compared with 46 similar transfers reviewed retrospectively

Effect	Retrospective review (46)	Flying squad (38)	Significance
hypotension (sustained fall greater than 40 mm Hg to under 80 mm Hg)	6	0	$P < 0.05$ χ^2 test
hypertension (sustained rise of 30 - 50 mm Hg)	6	3	
fits	1	1	
increased arterial P_{CO_2} decreased arterial P_{O_2}	6 of 13	6 of 38	$P < 0.03$ Fisher's exact test

TABLE XIII

Cause of sustained clinical effects observed by ITU flying squad (38 patients)

Effect	Number of patients	Probable cause	Number of patients
INDIRECT:			
Sustained hypertension	3	changed IPPV	2
		over-transfusion	1
BP 100/65 → 85/50	1	changed IPPV	1
Increased Pco_2	3	changed IPPV	2
		changed oxygen therapy	1
Decreased Po_2	3	changed IPPV	1
		changed oxygen therapy	1
		narcotics	1
DIRECT:			
Fit	1	start of ambulance movement	1

TABLE XIV

Mean clinical parameters before and after transfer in 17 patients transferred 3.5 - 17 miles (mean 10 miles)

Parameter	Units	Before	After
heart rate	beats/min	103	105
blood pressure	mm Hg	126/75	128/75
CVP	cms H_2O	11.5	12
urine output	ml/hour	125	140
toe temperature	°C	29.0	27.7*
rectal temperature	°C	37.4	37.6
respiratory rate	/min	18	19
pH		7.41	7.40
Po_2	mm Hg	68	65
Pco_2	mm Hg	39	42
base excess	meq/l	0.5	1.5

*$P < 0.0005$ (Paired "t" test)

No other changes statistically significant.

Discussion

ITUs are extremely expensive in money, equipment and staff. Whatever the long-term ideal, at present there is no prospect of providing an ITU for every district hospital. If patients in these hospitals are to receive ITU facilities, then better use could be made of existing ITUs which are mainly in large, central hospitals.

ITU facilities may be taken to the patient or the patient brought to the ITU. The present flying squad takes virtually full ITU facilities to the patient for the initial phase of resuscitation. This, however, is costly in staff time and could not be maintained for more than a few hours. Patients must be brought to a central unit for continuing care and to permit maximum utilisation of special equipment and highly trained staff[86]. With present resources there is no alternative to transporting such patients to the ITU.

For transport of critically ill patients to be acceptable, it should be proven that the benefits of ITU treatment outweigh the risks of transport. Indeed for wider acceptance, and in the absence of any objective, quantitative analysis of the value of ITUs, it must be shown that harmful effects of transport are absolutely minimal. Despite previous clinical impression, the present study has shown that, with an ITU flying squad, ambulance transport causes relatively minor effects. No patients died during, or as a direct result of, transport and most of the effects seen have been rapidly reversible. The flying squad introduced several factors: it encouraged earlier referral, patients were resuscitated and stabilised before transfer and had continuing ITU treatment throughout the journey; this permitted a slower, smoother ride. The relative importance of these factors is uncertain, but together they appear to make the transfer of critically ill patients feasible.

DISCUSSION

Both the mountain rescue and obstetric flying squad reviews showed little evidence of harmful effects of transport. In the ITU review the 28% incidence of cardiovascular change during transfer was comparable to that reported by other workers in similar studies[39,43], though there has been no previous report of hypertension, delayed hypotension or increased Pco_2. In other situations, however, hypertension is a common response to stress. The general stability of the mountain rescue and obstetric flying squad patients and the more labile BP in obstetric patients whose initial HR was more than 110/min., together with the increased incidence of cardiovascular change seen in ITU patients with an initial body temperature of less than 36°C and the higher final mortality in patients who showed cardiovascular changes during transfer, all suggest that cardiovascular changes during transport are more likely to occur in illor patients. Retrospectively it is difficult to determine if these changes were direct or indirect effects of transport, or merely coincidental. Patients with septic shock and chest injuries (both crushed chests in the ITU review and chest injury in the mountain rescue review) appeared to be particularly likely to show such changes.

The flying squad introduced changes in procedure for the transfer of critically ill patients. As a result, in 20 patients clinically monitored during ambulance transfer to the ITU, there was no change in mean cardiovascular, respiratory, fluid balance or temperature parameters. One patient became hypertensive due to over-transfusion, one had a fit, but none became hypotensive. Delayed hypotension was shown to be an effect of changed treatment after arrival at the ITU. The incidence of blood gas changes was reduced from 46% to 15% -

all related to changed treatment en route. With the exception of the fits, all the changes seen in both the retrospective ITU review and the first phase of the flying squad were sustained effects: clinical monitoring would not have detected transient effects.

Routine ambulance transport of 20 convalescent surgical patients did not cause clinically significant changes in any variable, either individually or mean, again confirming that effects of transport are largely limited to seriously ill patients.

Intra-arterial monitoring supported and amplified the above findings. Sustained effects - blood pressure and blood gas changes - were again caused indirectly by changed or inadequate treatment. Direct effects, in contrast, were transient and there was generally striking cardiovascular stability. Transient hypertension occurred repeatedly in seven out of 11 patients, while only four minor episodes of transient hypotension were observed in two of the 11 patients. This is in complete contrast to previous literature[21,24,39,40] which emphasises hypotension and makes no mention of hypertension. It is, however, in keeping with the findings in the earlier stages of this study. Although Pichard et al[39] eliminated inadequate treatment before transport, hypotension may have been reduced in the present studies by meticulous attention to maintaining treatment throughout the journey. The increased incidence of ventricular extrasystoles during movement confirms earlier clinical impression[36]. All these transient effects were significantly more frequent during movement to and from the ambulance than during the ambulance ride, suggesting that previous emphasis on the ambulance ride[21,30,39,40] may have missed the equally important, and often more time-consuming, beginning and end of the journey. The clinical importance of these transient effects remains uncertain, though none was observed to cause harm.

The results to date encourage hope that detailed improvement in treatment during ambulance transport may reduce the ill effects still further. It already appears that improved respiratory and cardiovascular support may virtually eliminate the sustained BP and blood gas changes seen in the early stages of the study. Airway and mechanical respiratory problems may be forestalled by instituting any necessary measures before starting transfer[38]. Fits might be prevented by transfer under heavier sedation[44]. The transient phenomena might also be reduced by appropriate measures. The trauma of lifting the patient on and off the trolley might be reduced if a stretcher replaced the hand-lift. Heavier sedation, particularly of patients on IPPV, might reduce the incidence of transient hypertension, while intravenous lignocaine may be indicated before transfer in any patient with extrasystoles. Individually simple though collectively demanding, such attention to detailed maintenance of treatment should make ambulance transport of critically ill patients even safer.

The evolution, equipment, organisation and function of the ITU flying squad has been described, with the logistical, clinical and investigative advantages of secondary over primary evacuation. The safety of transferring critically ill patients to a central, Area ITU has been shown by an analysis of 38 patients transported distances up to 17 miles without serious harm. This suggests a possible pattern for future regional organisation of ITU facilities, though there remain practical problems in full implementation and utilisation of such a service. Transfer of a small number of patients has required a considerable liaison effort with the referring hospitals and there has been only a limited demand for the facilities. Expansion should occur with the opening soon of a new 12 bedded ITU in the Western Infirmary which should make possible a true Area Intensive Therapy Service.

Numerically, primary evacuation of patients from the site of collapse or injury is much more important than secondary evacuation between hospitals. Secondary evacuation has many advantages for detailed study and obtaining scientific information, but for greatest benefit the results should be applicable to the practical situation of primary evacuation. Many of the present results can be so applied. Critically ill patients - those likely to die within a few hours if they do receive life-support - will still be at highest risk. The patho-physiological effects of transport are likely to be basically similar with changes in emphasis in different types of patients. The indirect effects of transport are again likely to be more important, and provision and maintenance of a high standard of treatment should show larger dividends than costly experiments in ambulance design. Movement to and from the ambulance requires as much attention as the ambulance ride and patients should be lifted as little and as carefully as possible. Such principles seem applicable: their simplicity should not belie their importance.

PART III : STUDIES ON THE EFFECTS OF MOVEMENT

a) Effect of movement on haemorrhagic shock dogs

b) Movement of post-operative patients

c) Movement of critically ill patients within hospital

Discussion

IIIa : EFFECT OF MOVEMENT ON HAEMORRHAGIC SHOCK DOGS

There are no reported studies on the effect of any type of movement on ill, injured or shocked animals. A close similarity has been reported in the cardiovascular response of unsedated supine humans and healthy anaesthetised dogs to low frequency X axis vibration on a vibration table[67,69]. Sustained, single frequency, single axis vibration is not, however, the most important characteristic of the ambulance ride[21,39]. Isolated clinical reports[21,24,39,40] suggest that sudden jolting of the ambulance may be more important.

There are also isolated clinical reports[3,47] of harm resulting from head up tilt. No published experimental data on head up tilt could be traced, though Campbell[48] found no change in BP or COP when cats with haemorrhagic shock were tilted head up or head down.

The present investigation studied the effect of ten minutes repeated jolting and ten minutes head up tilt on lightly anaesthetised dogs with severe haemorrhagic shock.

Materials and methods

17 healthy adult greyhounds which had already been used for other experiments were kept under light anaesthesia via a cuffed endotracheal tube. Half were breathing spontaneously and half were paralysed with suxamethonium chloride (50 mg) and ventilated using a Palmer pump (IPPV). Portex cannulae were inserted in the right femoral artery and vein by cut-down. The arterial cannula was advanced into the abdominal aorta and the venous cannula into the right atrium under fluoroscopic control. Aortic pressure (BP) and right atrial pressure (RAP) were measured using capacitance transducers (Elema Schönander EMT 35 and 33 respectively) and recorded with the ECG (lead II) on an Elema Schönander ink writing recorder (Mingograph 81). Mean BP (mBP) and mean RAP were obtained by integration and HR counted from the ECG. COP was measured by the dye dilution technique[87]. 2,500 units of heparin were given intravenously.

At the start of each experiment the dog was bled via a catheter in the left femoral or left carotid artery until mBP was 40 mm Hg. Further small amounts were bled over the following 15 - 60 minutes to maintain mBP at this level until it was stable. No further blood was removed thereafter. Two sets of readings ten minutes apart confirmed stability of the preparation.

Of the 17 animals, six died during bleeding or stabilisation, leaving 11 for detailed study. In the first three, data was incomplete and is not included, although the changes were similar to those reported. Of the eight dogs reported, five had one study only. Two dogs had both a jolting and a tilting study with re-stabilisation between. One dog breathed spontaneously during a jolting study, and after a period of retransfusion was paralysed, re-bled and used for further jolting and tilting studies under IPPV.

After stabilisation, six dogs were subjected to ten minutes jolting. The dogs lay supine tied to a 50 Kg table on small solid rubber wheels on a stone floor. The table was shaken, jolted and rocked in three axes and lifted and dropped two to three inches by four people. Acceleration was measured during one experiment by an Ether Blaz accelerometer strapped to the dog's chest and recorded on the Mingograph 81 (Fig. 20). After four minutes there was a ten second rest to record ECG, BP and RAP. After six minutes there was a 15 - 30 second rest to measure COP. After ten minutes movement was stopped and ECG, BP, RAP and COP immediately measured. These measurements were repeated after ten minutes rest.

After stabilisation six dogs were subjected to ten minutes 15° head up tilt. The BP and RAP transducers were lifted level with the estimated position of the right atrium and re-zeroed. ECG, BP and RAP were slowly recorded continuously. A faster recording and a measurement of COP was obtained at five and ten minutes. The table was then returned to the horizontal and the transducers re-zeroed. Continuous slow recording at rest was followed by a faster recording and a COP measurement after ten minutes.

Results

In the jolting studies there was no pattern of change in HR or RAP. Five of the six dogs had a rise in BP - systolic, diastolic and mean. BP generally rose over the first one to two minutes and, at the end of movement, fell over a similar period (Fig. 21). The one dog to have a fall in BP was already deteriorating at rest. All six dogs had a rise in COP.

Head up tilt did not influence HR. Four of six dogs had a fall in BP - systolic, diastolic and mean - and the other two were progressively recovering. In one the fall in BP was immediate on tilting (Fig. 22). More commonly. however, the fall in BP was slower as in the one animal to die apparently as a result of the procedure (Fig. 23). Recovery was usually within a few seconds of ending the tilt. Five had a fall in RAP. Two had a marked fall in COP. In one these effects led to asystole (Fig. 23).

The accelerometer readings during jolting (Fig. 20) showed a main frequency of approximately 1.5 Hz with lower amplitude secondary vibrations at higher frequencies. The peak amplitudes of the 1.5 Hz vibration were 3 g, 1.5 g and 1.5 g in the X,Y and Z axes respectively.

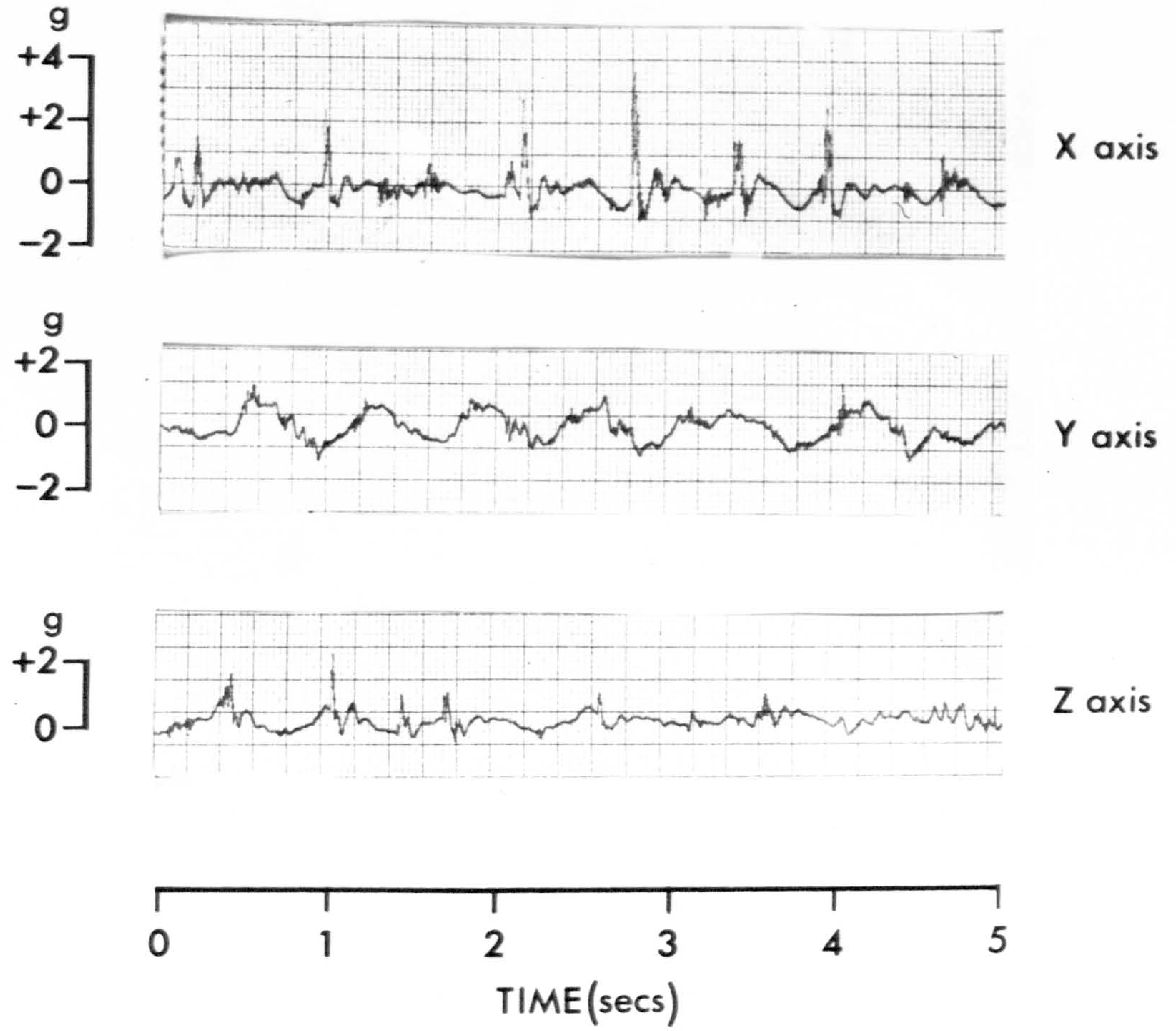

FIGURE 20. Study IIIa: accelerometer readings during jolting.

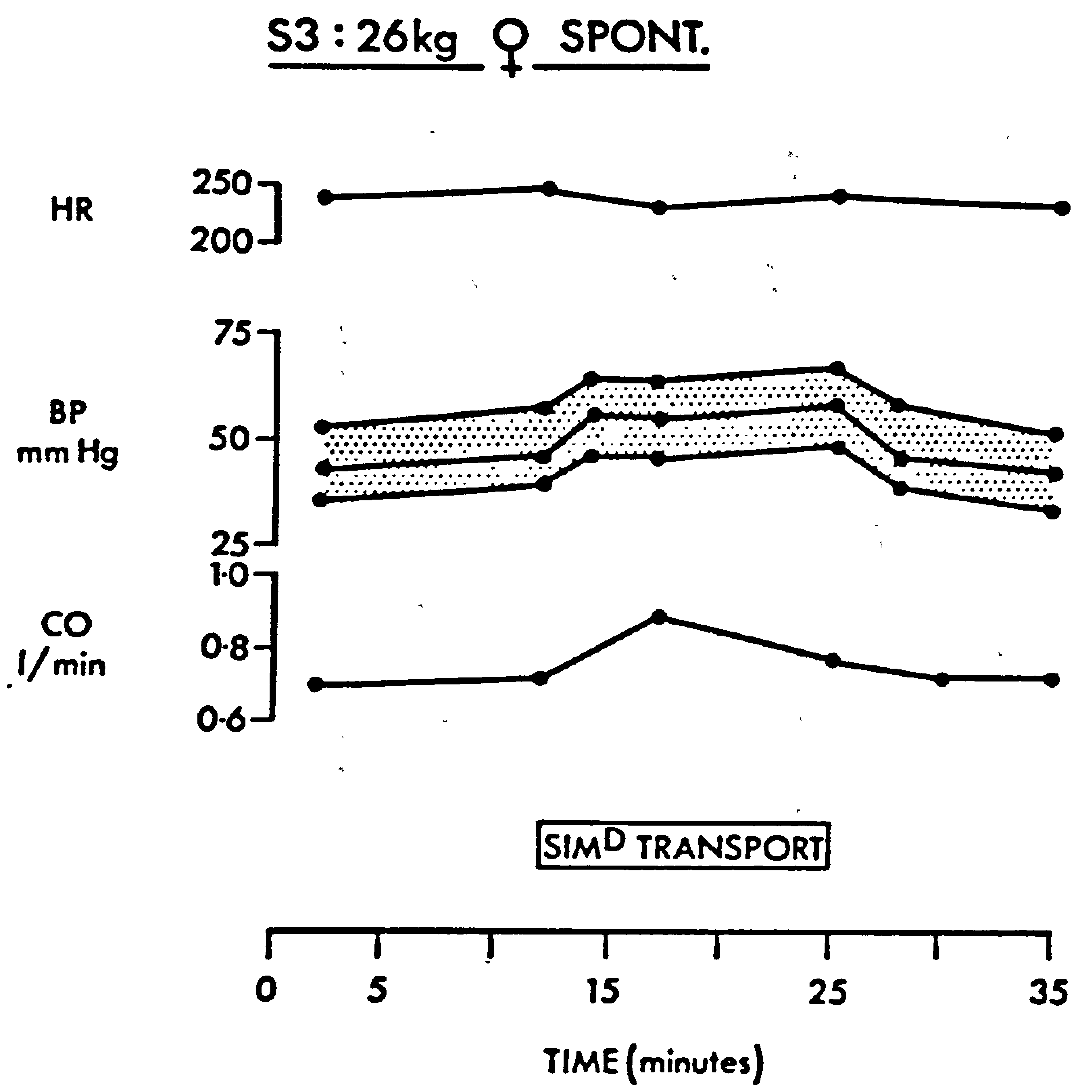

FIGURE 21. Study IIIa: one example of a dog's cardiovascular response to jolting.

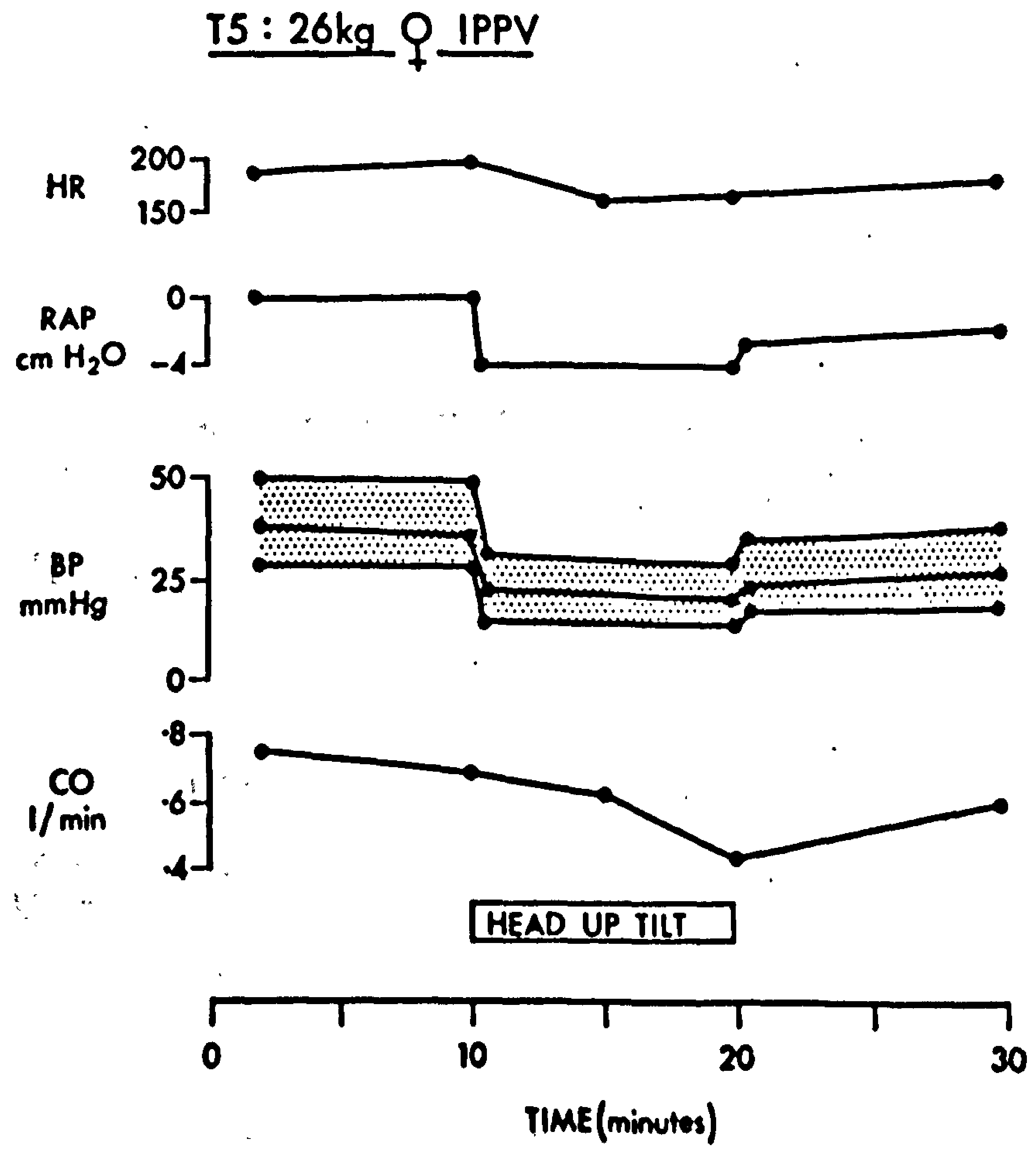

FIGURE 22. Study IIIa: one example of a dog's cardiovascular response to 15° head up tilt.

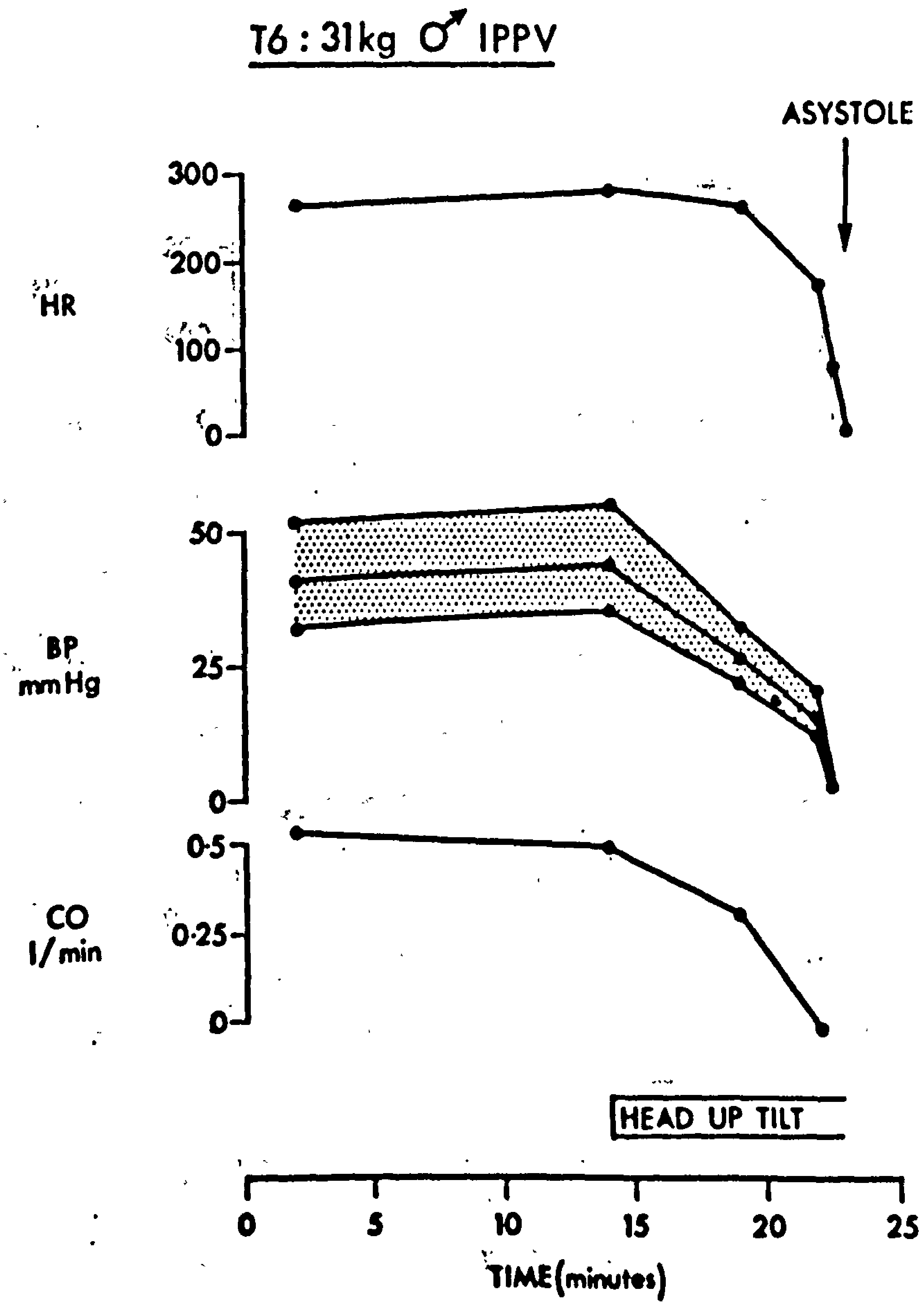

FIGURE 23. Study IIIa: death occurring in one dog during head up tilt.

Discussion

Ideally, proof of cause and effect depends on the sequence - stability, stimulus, effect, end stimulus, end effect, return to previous level of stability. In the jolting studies this full sequence of changes was seen in BP in three of six dogs and in COP in three. In the tilting studies the full sequence was seen in BP and COP in one dog. Parts of the sequence were seen in most of the other animals. It may be concluded that these changes were due to the experimental procedure.

Measurements should be reliable. HR measurements were reliable. By avoiding recording during movement, artefact was avoided in BP and RAP measurements though in the tilting studies the problem of changing the zero casts some doubt on the RAP measurements. In the jolting studies, by only measuring when movement was stopped, the ECG, BP and RAP readings would only reflect steady state changes and any rapid fluctuations in response to movement would be missed. The dye dilution measurement of COP had an error of ± 10%[87], and some of the changes observed were not much greater than this.

The pattern of accelerometer readings was somewhat similar to that reported in ambulances by Pichard et al[39]. Although less well controlled, this simulation seems closer to an ambulance than the one axis, single frequency, constant amplitude vibration used in previous studies.

Stability in this preparation was difficult to achieve. After a period of continued bleeding to maintain mBP at 40 mm Hg, dogs normally begin to take up blood to sustain mBP. This take-up point is generally regarded as the onset of irreversible shock[88]. The brief period between no longer requiring further bleeding and beginning to take up blood was used for this experiment. This period may be short and cannot be judged accurately in advance. In five of the 12 experiments BP and COP appeared to be recovering throughout, while in one they appeared to deteriorate throughout.

Although not strictly comparable, the changes seen during jolting may be contrasted with those seen in healthy dogs on a vibration table[67,69]. The lack of changes in HR, compared with the rise seen in unshocked dogs[67,69] may be due to the fact that shocked dogs already have almost maximal sympathetic activity and are unable to increase HR any further. The rise in BP is difficult to compare. It may be that the vasoconstriction of shock prevents the fall in peripheral resistance reported on vibrating unshocked dogs[69]. The rise in COP is comparable to that in unshocked dogs[67,69]. The changes in shocked dogs appear to be largely cardiac in origin, while the peripheral effects may be masked by the shock process.

The marked fall in BP and COP on tilting, in one case leading to asystole, confirms clinical impression. The fall in RAP suggests that the mechanism may be related to diminished venous return from the lower body. 10° head up and head down tilt was performed in a 78 year old man with haemorrhagic shock following prostatectomy (Fig. 24). The hypotension during head up tilt was accompanied by pallor, sweating and air hunger and tilting was rapidly discontinued. These results strongly suggest that head up tilt should be avoided when moving shocked patients.

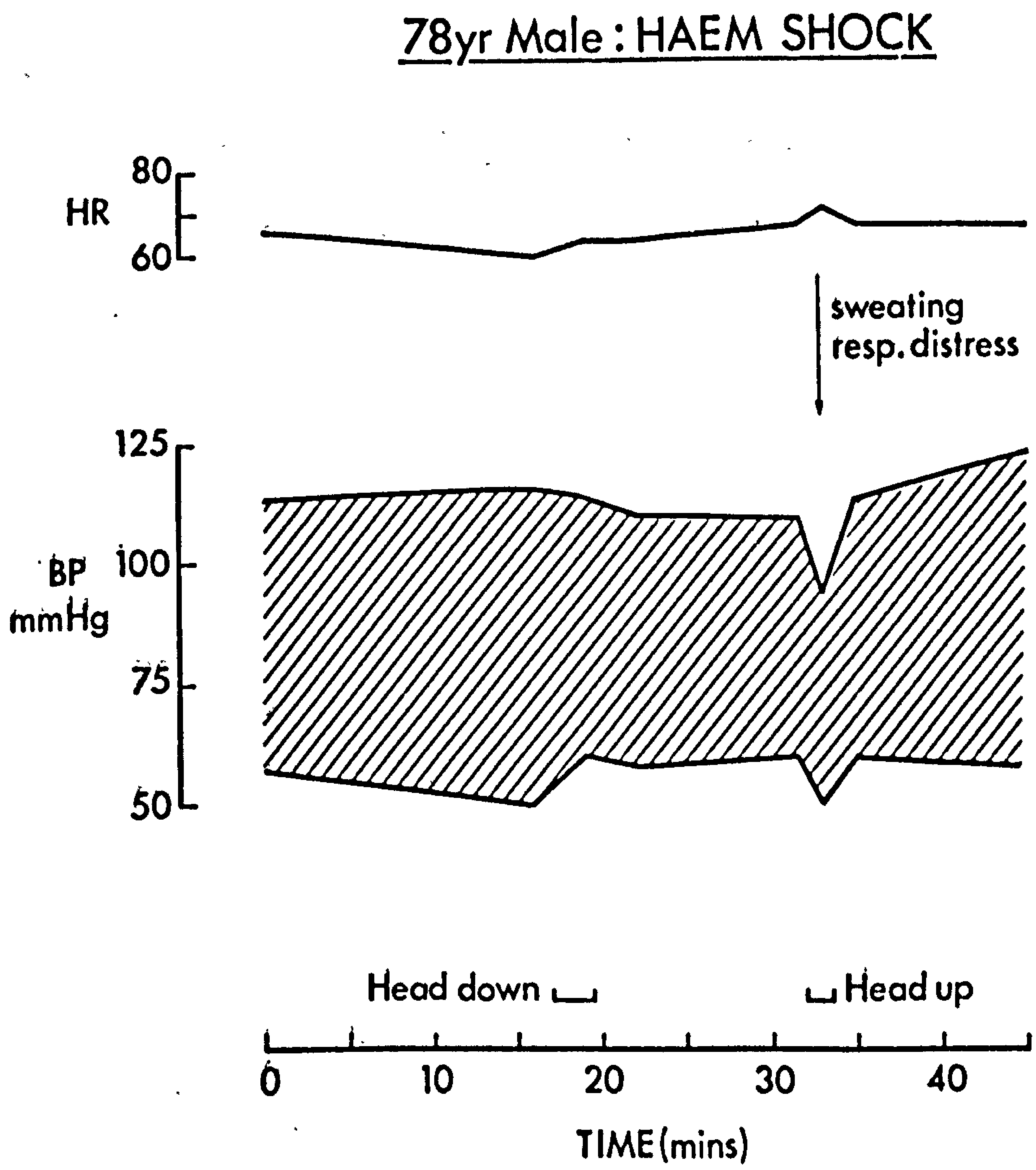

FIGURE 24. Cardiovascular effects of tilting a 78 year old man with haemorrhagic shock after prostatectomy.

Earlier clinical studies had given an impression that IPPV might have some protective action against the effects of transport in critically ill patients. In the present study both the effects of tilting and to a lesser extent those of jolting appeared more marked in those dogs on IPPV. The one dog subjected to jolting both breathing spontaneously and on IPPV showed a very similar response under both conditions. No evidence was found to suggest that IPPV has any protective action against the effects of movement.

IIIb : MOVEMENT OF POST - OPERATIVE PATIENTS

The early studies produced a clinical impression that patients recovering from a recent operation and anaesthetic were more vulnerable to movement. In the only reported study, Weller[46] found 11 of 22 patients had a rise in BP when moved from theatre to ITU after cardio-pulmonary by-pass, while three had a fall of up to 15 mm Hg. There was a variable change in HR and no appreciable change in ECG.

The present investigation of routine post-operative patients aimed to detect any vulnerability to movement.

Patients and methods

70 post-operative surgical patients were studied during their return from the operating theatre to the ward. The majority had major elective surgery such as gastro-intestinal resection, joint replacement, thoracotomy or arterial graft. In 60 patients three clinical readings of HR and BP - the last immediately before movement-confirmed stability before movement. Readings were repeated immediately after movement and 5, 15 and 30 minutes thereafter. All readings were made by one observer who did not interfere with the usual routine of the nursing or porter staff executing the move.

In ten patients BP was recorded by a radial artery catheter, capacitance transducer (Elema Schönander EMT 35) and an Elema Schönander ink writing recorder (Mingograph 81). After baseline readings at the end of the operation, a continuous record was made while the patient was lifted by stretcher from the operating table to a trolley.

Results

All patients were stable during the pre-movement control period. In the 60 patients with clinical readings, mean HR immediately before movement was 89/min, while immediately after movement it was 91/min. The corresponding BP means were 127/74 and 128/73. Three patients had a rise in HR of 24 - 40/min. SBP rose 15 - 20 mm Hg in two patients and fell 14 mm Hg in one. All returned to previous levels within five minutes of stopping movement. No other patient had a rise or fall in HR of more than 12/min or in BP of more than 10 mm Hg. None of the intra-arterial recordings showed any significant change. Two patients vomited, one while being wheeled to the ward in bed, the other two minutes after being lifted from trolley to bed in the recovery room. In one patient a suction drain caught in a doorway and was disconnected.

Discussion

No evidence was found to support the initial clinical impression. All 70 patients showed remarkable stability, confirming Weller's findings[46]. Provided adequate care is taken, post-operative patients do not appear to be particularly susceptible to movement.

IIIc : MOVEMENT OF CRITICALLY ILL PATIENTS WITHIN HOSPITAL

Despite considerable interest in ambulance transport, there is little information on the effect of moving critically ill patients within hospital. Apart from Weller's study[46] on patients after cardiopulmonary by-pass, the only report is by Taylor et al[45]. With ECG monitoring of high risk cardiac patients moved within hospital, they found 90% had a rise in HR and two of 50 appeared to develop arrhythmias in response to movement.

The present clinical study looked at the effect of intra-hospital movement on critically ill patients moved to and from the ITU of the Western Infirmary.

Patients and methods

In the five month period of the study, 55 patients were admitted to the ITU of the Western Infirmary. These 55 patients had 86 moves to and from the referring units or theatre during the acute phase of their illness. All moves were carried out in a routine manner by the medical and nursing staff of the ITU. In 33 moves in the 20 most ill patients, detailed clinical observations were made of the period before, during and after the move by an uninvolved observer. No special measures were taken and as far as possible the observations did not interfere with the routine execution of the move. Baseline readings for at least 30 minutes before movement allowed patients to act as their own controls. No major clinical deterioration was noted during movement of the remaining 35 patients.

Results

Significant effects of movement were seen in seven patients (Table XV). These patients were stable before movement and the reported phenomena appeared to be caused by movement. The cardiovascular changes, transfusion requirements and fall in haemoglobin from 12 to 6 G/100 ml in Patient 1 (Fig. 25) were consistent with movement causing renewed bleeding. Figure 26 shows the recordings of Patient 2 while Figure 27 shows the ECG before and after movement. Figure 28 shows the BP in Patient 5.

During the control baseline period, only one patient showed progressive terminal hypotension and no other cases of sudden collapse or cardiac arrest were observed. Two patients had a transient fall in SBP to 70 - 75 mm Hg and a further two showed a rise of 30 - 50 mm Hg, all related to changes in IPPV. One patient showed spontaneous reversion from supra-ventricular tachycardia to sinus rhythm. Collapse during movement was significantly more frequent than during the baseline period ($P < 0.04$, Fisher's exact test, attaching equal weight to each patient's 30 minute baseline period and 5 minute movement period).

TABLE XV

STUDY IIIc : Five months experience of movement of critically ill patients within hospital

Patient	Age	Sex	Diagnosis	Move	Effect
1	11	M	Fractured pelvis	Theatre to ITU	Re-bled - death
2	54	M	CCF, Pulmonary emboli	Ward to ITU	Atrial fibrillation Hypotension
3	56	M	Mediastinal haemorrhage	Resuscitation room to ambulance	Airway obstruction
4	67	M	Bleeding aortic aneurysm	Theatre to ITU	Hypertension
5	46	F	R. haemothorax	Rolled on to left side (in theatre)	Hypotension
6	91	M	Pulmonary embolus	Ward to ITU	Hypotension - death
7	38	M	Crushed chest, haemothorax	ITU to theatre	Cardiac arrest - death

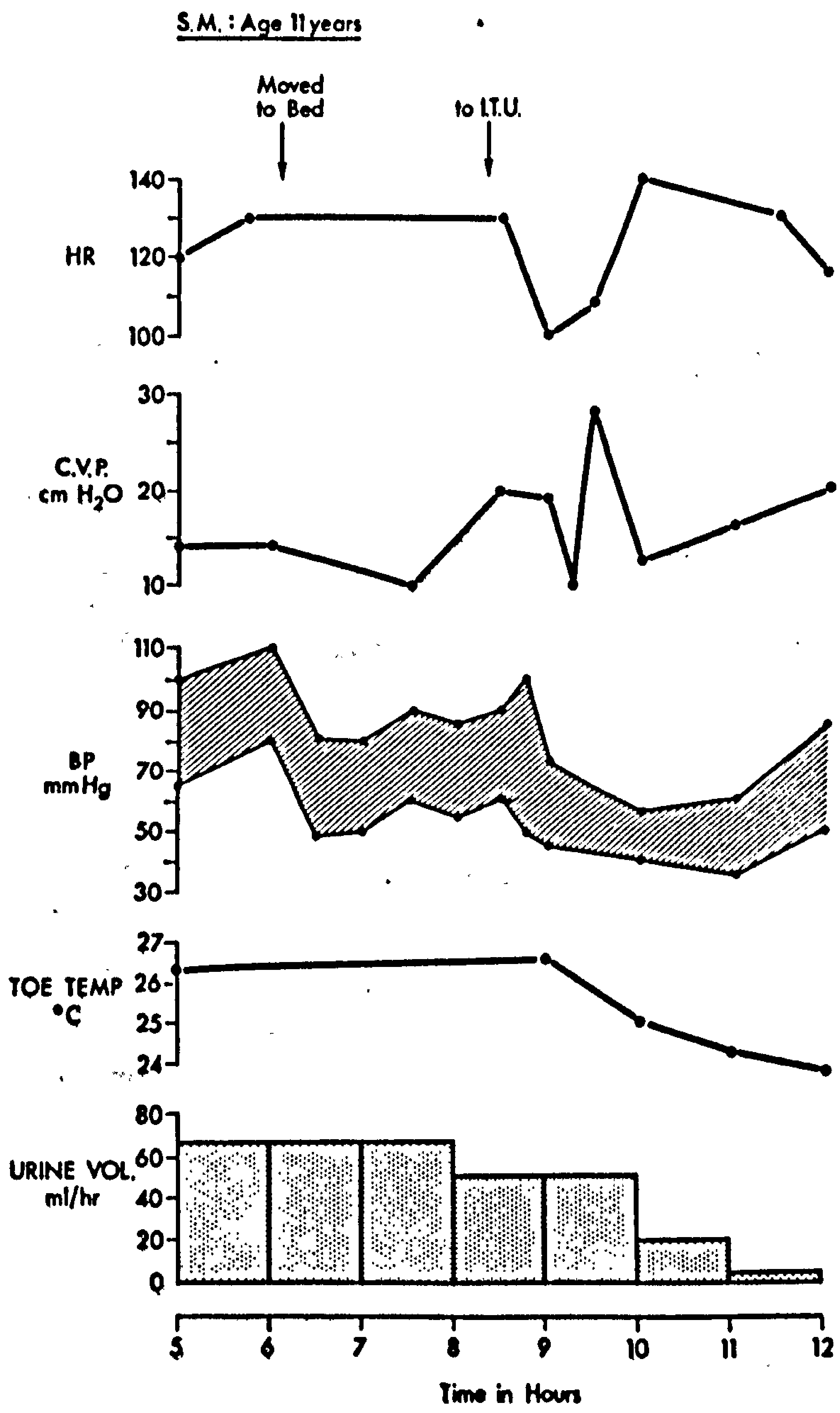

FIGURE 25. Study IIIc: Patient 1 - recordings when moved from theatre to ITU. Patient had lain undisturbed on the operating table for six hours after the end of an operation for bleeding from a crushed pelvis.

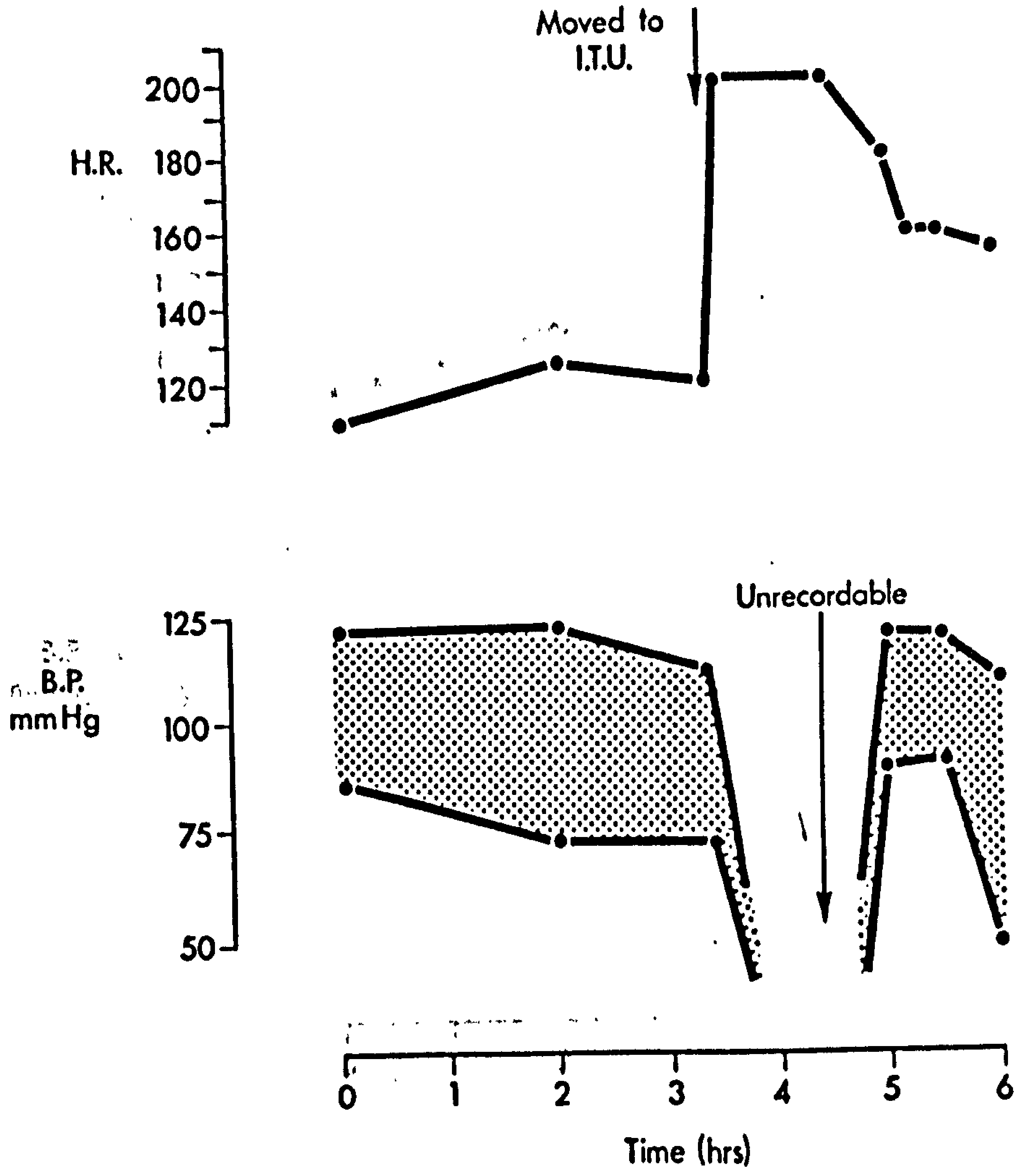

FIGURE 26. Study IIIc: Patient 2 - cardiovascular recordings in a patient with cardiac failure and pulmonary emboli moved from ward to ITU.

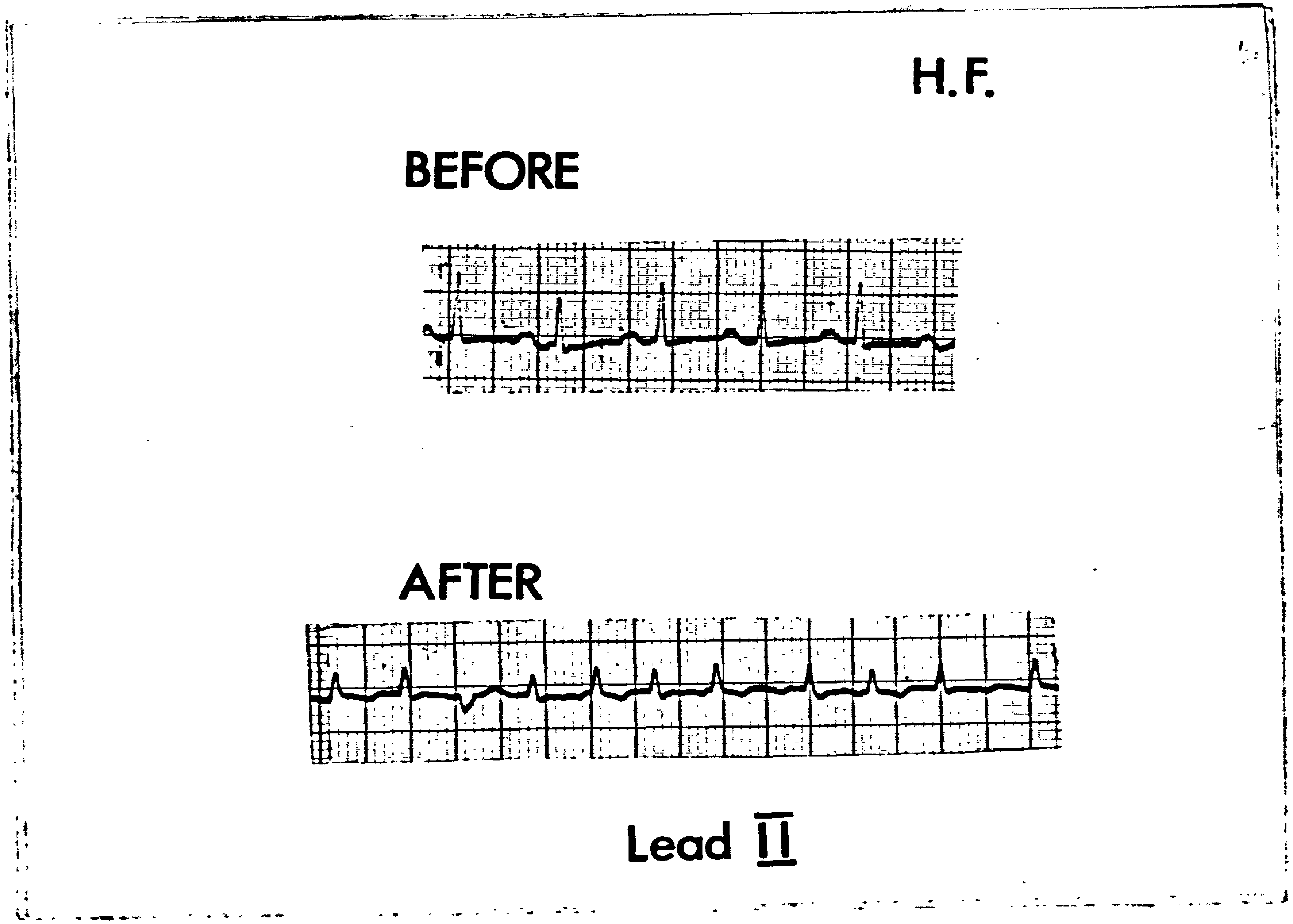

FIGURE 27. Study IIIc: Patient 2 - ECG 30 minutes before and 15 minutes after movement.

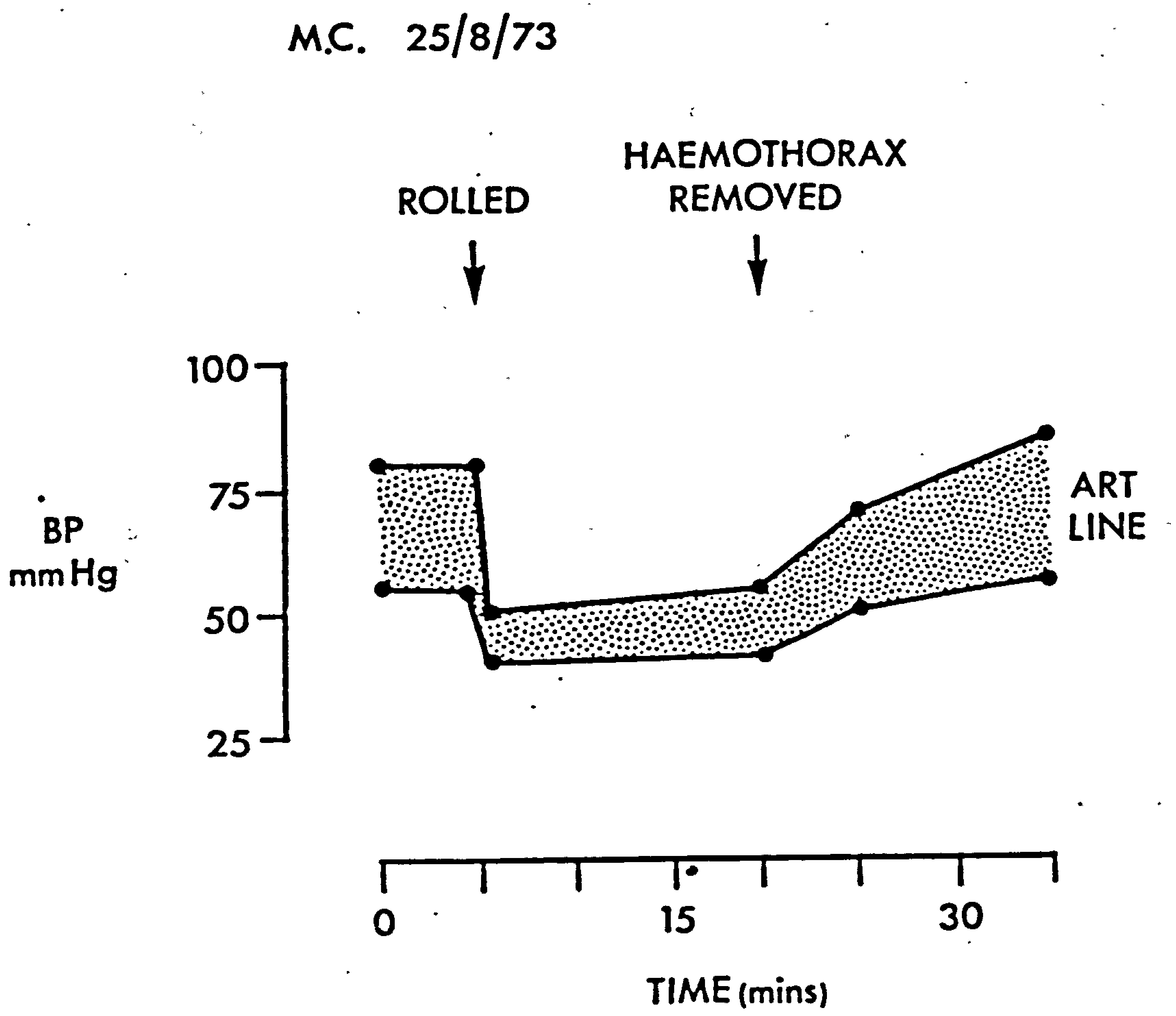

FIGURE 28. Study IIIc: Patient 5 - BP recording in theatre. Effect of rolling patient on to her side with a haemothorax uppermost.

Discussion

One critically ill patient per month suffered major cardiorespiratory collapse or death as a result of movement within hospital. Though similar incidents do occur in other hospitals[89,90] this was a surprisingly high frequency. So far as possible the study reflected normal routine in the hospital. Any unintentional influence the observer might have had would probably have improved standards, so this incidence will tend to be an under-estimate rather than an over-estimate.

Many of these patients might have been expected to die in any event. Nevertheless, only one patient deteriorated during the control period. Baseline readings showed that at that point in time most were relatively stable and the phenomena observed during movement were significantly more frequent and appeared to be a direct result of movement. The mechanisms were varied. In Patient I movement of a major fracture caused renewed bleeding[21,24]. In Patient 2 movement appeared to precipitate arrhythmia[32,45]. The haemothorax in Patient 5 appeared to cause direct pressure on the heart or great veins when she was rolled on to her side. In Patients 1 and 6 movement may have precipitated cardiovascular decompensation with a fall in BP and a rise in CVP. Collapse was particularly frequent ($P = 0.07$, Fisher's exact test) in patients with intra-thoracic bleeding (Patients 3, 5 and 7).

The effect of movement may be direct or indirect[21]. Indirect effects were clearly illustrated by difficulty in maintaining an airway (Patient 3) or IPPV (Patients 4 and 7). Even such simple measures as traction for a fracture (Patient 1) or a suction drain (Study IIIb) can easily be disturbed while moving along narrow corridors or into elevators.

The incidence of serious effects due to intra-hospital movement in critically ill patients was much higher than that previously seen during ambulance transport of similar patients. This may be partly due to a willingness to move patients within hospital who would be considered too moribund to subject to an ambulance journey. It is probably also due to less thorough preparation and less adequate maintenance of therapy during movement. In the ambulance studies, every possible care was taken to stabilise the patient and then maintain every aspect of treatment unchanged throughout the journey. When simply wheeling a patient along a corridor it is tempting to imagine that there is less opportunity for misfortune and that a few minutes gap in treatment will do no harm. This study suggests that in critically ill patients this is untrue: movement of critically ill patients within hospital may be as hazardous as an ambulance journey. Serious consideration should be given to the need for movement in such patients. Adequate preparation for the move is essential and every possible care should be taken to maintain treatment and forestall "accidents" during the move. Such patients should not simply be consigned to the care of non-medical or inexperienced staff.

DISCUSSION

The jolting experiments on dogs with haemorrhagic shock confirm the tendency to hypertension seen in the ambulance studies. The harmful effects of head up tilt clearly confirm isolated clinical reports[3,47] and suggest that this position should be avoided when moving shocked patients. No evidence was found that IPPV has any protective value. In view of the practical problems seen earlier in maintaining IPPV during ambulance transfer, this confirms that IPPV should only be used when it is clinically essential: there is probably no intrinsic advantage to IPPV during transfer.

The study on post-operative patients again confirms the relative stability of routine patients and provides no support for the clinical impression that patients recovering from a recent operation and anaesthetic are vulnerable to movement. This implies that there is no reason per se for delaying the transfer of such patients.

In the study on ITU patients moved within hospital, one patient per month suffered major cardiovascular collapse or death as a result of movement, confirming the dangers of movement to and from the ambulance. The apparently greater danger of movement within hospital is paradoxical. Partly it may have been due to a willingness to move patients within hospital who would have been considered too moribund to subject to an ambulance journey. Most important, however, it appears to confirm the importance of maintaining life-support during movement. The intra-hospital study documented the routine performance of moves by the regular hospital staff and deliberately refrained from introducing any special measures. Conversely, in the prospective ambulance studies every possible care was taken to stabilise the patient and then maintain treatment as fully as possible during transfer. During movement within hospital, the effects seen were comparable to those previously reported during ambulance transport: renewed bleeding of a pelvic fracture[21,24], cardiac arrhythmia[36,37,45], cardiac embarrassment due to a haemothorax and cardiac decompensation. The high incidence of collapse in patients with intra-thoracic bleeding supports the findings of the initial retrospective reviews of mountain rescue transport and ITU transfers. The difficulty observed in continuing treatment during movement, particularly in maintaining an airway and providing adequate IPPV, yet again confirms the importance of the indirect effects of transport.

Integration of the present results with previous literature may expand our understanding of the effects of transport.

Critically ill patients - those requiring life-support or likely to die if it is delayed more than a few hours - are at highest risk during transport. Particular patients at high risk include those with:

cardiovascular instability[39]:

recent myocardial infarction[5,30]
massive haemorrhage[39]; shock; septic shock
pulmonary embolus[39]
major chest injuries; intra-thoracic bleeding

neurological vulnerability[39]:

conditions liable to fits[39]; tetanus[44]
encephalopathies[39]
high cervical fractures[39]

liability to upper airway obstruction[38]:

unconscious

facio-maxillary injuries; haemorrhage into upper airway

obstruction of upper airway

The effects of transport may be direct or indirect[21]. Pain, anxiety and the physical stimuli of movement may directly affect the patient's condition. Indirectly, lack of facilities and the motion of the ambulance may limit the ability of attendants to provide life-support, affecting the patient by changed or inadequate treatment. Sustained effects appear to be caused indirectly and are clinically more important and harmful. Direct effects appear to be transient and are of uncertain clinical significance.

Clinically, the most important consequences of movement are:

cardiovascular:

hypertension

hypotension[21,39,40]

delayed hypotension

arrhythmias[5,30]; ventricular extrasystoles[36]

pulmonary embolus[39]

respiratory:

respiratory failure[40]; increased Pco_2; decreased Po_2 ;
acute upper airway obstruction

fits[39,44]

Ambulance transport does not significantly affect:

rectal temperature

basic ECG pattern (apart from extrasystoles and rarely arrhythmias)

HR and RR (usually only minor, transient rises)

pH; base excess

transfusion requirements; urine production

Movement within hospital and especially lifting in and out the ambulance and from trolley to bed and vice versa may be more hazardous than the actual ambulance ride. Head up tilt should be avoided in shocked patients.

The incidence of serious effects of ambulance transport, especially those caused indirectly, may be significantly reduced by resuscitation and stabilisation before transfer, maintaining life-support throughout the journey and a slower, smoother ambulance ride. The relative importance of these factors is uncertain.

The results of the current studies suggest many lines for further research. The relative importance of prior resuscitation and stabilisation, maintenance of treatment during transfer and a slow, smooth ride needs to be determined. Application of present knowledge to providing better treatment during transport should make both ambulance transport and movement within hospital even safer: this hypothesis needs testing on a wider scale and further confirmation. It also requires further assessment in the context of primary evacuation. The concept of an ITU flying squad may now be expanded and the long-term, practical provision of an Area Intensive Therapy Service examined. The present experimental technique could be used to compare different ambulances, different ambulance beds, helicopter and fixed-wing air ambulance transport or for animal experiments. More sophisticated cardiovascular and respiratory measurements might yield new information on transient phenomena.

The present studies might be claimed to have clarified some of the basic principles of how movement affects critically ill patients. Detailed investigation of small groups of patients has helped to understand and correlate limited observations on large groups of patients, isolated clinical reports and general clinical impression. Integration has improved understanding of certain broad principles of transport and focused attention on previously neglected aspects. Further application of these principles is required from the specific study situation to the wider practical provision of routine transport. Much fine detail is still missing. In the long term, however, basic scientific knowledge is essential for the development of rational policy. Hopefully, the present gap in medical responsibility during transport will be bridged as doctors become more aware of, more concerned with, and more involved in the movement and transport of critically ill patients.

CONCLUSIONS

1. a) Critically ill patients - those requiring life-support or likely to die if they do not receive it within a few hours - are most likely to show cardiovascular and respiratory changes or fits during transport. Patients with major chest injuries or intra-thoracic bleeding should be added to the list of those at particular risk.

   b) Indirect effects of transport - those caused by changed or inadequate treatment during the journey - appear to be clinically more important and harmful than the direct effects of the ambulance ride.

   c) Sustained clinical effects of ambulance transport appear mainly to be caused indirectly, while direct effects are usually transient.

   d) Movement to and from the ambulance, and movement within hospital, may be as hazardous as the actual ambulance ride. Head up tilt should be avoided in shocked patients.

   e) The effects of transport can be significantly reduced by improved treatment throughout the journey.

2. a) If ITU facilities are to be made generally available, they could be organised on a regional basis.

   b) An ITU flying squad working from a central ITU has been shown to be a feasible method of extending specialised facilities to serve peripheral hospitals.

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Kurzreferate/Abstracts

INTERNATIONALES SYMPOSION
über
MOBILE INTENSIVPFLEGEEINHEITEN
und Fortschritte auf dem Gebiet der Notfallmedizin

MOBILE INTENSIVE CARE UNITS
and Advanced Emergency Care Delivery Systems

24.–27. September 1973 in Mainz

CARDIOVASCULAR AND OTHER EFFECTS OF TRANSPORTING ILL PATIENTS

G. Waddell. (Glasgow)

In Scottish mountaineering accidents 3% of deaths occured during transport.

In 101 obstetric flying squad cases there was no clinical deterioration during the journey. There was no change in heart rate, blood pressure or foetal heart rate. Patients with an initial heart rate over 110/minute or clinical shock had a more labile blood pressure.

46 patients transferred by ambulance to an I. T. U. had no deaths during or immediately after the journey. The final mortality was similar to the unit's total mortality. 26 patients showed no response, 6 became hypertensive, 6 became hypotensive, one developed severe tachycardia and 7 developed hypotension 1 - 1½ hours after transfer. Half these responses had an apparent cause. Patients with the immediate responses had a significantly higher mortality: this may be an index of their condition rather than a cause/effect relationship. Patients whose temperature was 97°F or less showed more frequent responses. Septic shock patients most frequently showed responses and chest injury patients most frequently became hypertensive.

Body temperature did not change.

Repiratory rate, arterial pO_2 and pH did not change. Six of thirteen patients had a rise in pCO_2 of more than 10 mm Hg.

Kardiovasculare und andere Wirkungen beim Transport kranker Patienten

G. WADDELL

Bei Bergunglücken in Schottland entfallen 3% der Todesfälle auf die Zeit des Transportes.
In 1o1 Geburtshilfe-Einsatzflügen wurde keine klinische Verschlechterung während des Fluges festgestellt. Es gab keine Veränderung der Herzschläge, des Blutdruckes oder des Foetus-Herzschlages. Patienten mit einer ursprünglichen Herzschlagrate von über 110 pro Minute oder klinischem Schock wiesen einen labileren Blutdruck auf.
46 Patienten, die mit Krankenwagen zu einer ITU gebracht wurden, starben nicht während des Transportes oder sofort danach.
Die endgültige Todeszahl war ähnlich der totalen Zahl der Todesfälle der Einheit. 26 Patienten reagierten nicht , 6 wurden hypertensiv, 6 wurden hypotensiv, bei einem entwickelte sich eine ernsthafte Tachykardie und 7 entwickelten Hypotension 1 - 1 1/2 Stunden nach der Verlegung.
Die Hälfte dieser Reaktionen hatten einen ersichtlichen Grund.
Patienten mit unmittelbarer Reaktion hatten eine erstaunlich höhere Sterblichkeit. Das dürfte eher ein Anzeichen für ihren Zustand als eine Ursache-Wirkung Beziehung sein. Patienten deren Temperatur 97° F oder weniger betrug, zeigten vermehrte Reaktionen.
Patienten mit septischem Schock zeigten Reaktionen und Brustkorbverletzte wurden meistens hypertensiv.
Die Körpertemperatur veränderte sich nicht.
Atmungsrate, arterielles pO_2 und pH änderte sich nicht.
6 von 13 Patienten hatten einen Anstieg von pCO_2 um mehr als 1o mmHg.

Mountain rescue transport

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Mountain rescue transport

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Summary

Deaths on Scottish mountains during a thirteen-year period were reviewed. Only five of 175 fatalities occurred during the stretcher journey: 200 patients were carried down alive. This review produced little evidence of serious harm from mountain rescue transport.

MOUNTAIN rescue provides the most prolonged and arduous stretcher journeys in civilian practice. Seriously ill or injured mountaineers lie unattended for some hours before help arrives. After minimal first aid they are then subjected to several miles and often many hours of movement. Despite the greatest care by skilled and dedicated men, carrying a stretcher by hand across rough and treacherous ground, often in the dark, inevitably produces jolting and discomfort.

As detailed medical records are unobtainable in such conditions, large numbers of cases must be analysed. In this way, Pugh (1966) found suggestive evidence that head uptilt during transport caused fits and death in two patients with exposure. There is no other report on the detailed circumstances of mountaineering deaths or on the effects of mountain rescue transport.

The present analysis is of deaths occurring in Scotland from 1960 to 1972 inclusive. *Table I* shows the total numbers reported by the Scottish Mountain Rescue Committee and published annually in the Scottish Mountaineering Club journal. Aircraft crashes are excluded as virtually all victims died immediately. All other causes are included: injury, exhaustion and exposure or 'heart attack'. Possible deaths during the stretcher journey were identified from the above source, supplemented by reference to the leaders and records of all the main mountain rescue teams in Scotland. All sudden or accidental deaths are reported to the Crown Office who made available their full death records of possible interest.

CASE REPORTS

In only five cases was death found to occur in transit. All were previously healthy males aged from 17 to 26 years. Two occurred in 1962, one in 1965 and two in 1971; two in March and one each in April, October and December. Two occurred in the Ben Nevis area, two in the Cairngorms and one in Aberdeenshire. None of these factors differs from the overall pattern of Scottish mountaineering accidents.

Case 1

This man progressively collapsed from exposure and was assisted by members of his party for several miles. He was then carried one mile on a rope stretcher to a hut. When put on to the stretcher he was conscious but by arrival at the hut he had stopped speaking, appeared to be unconscious and only moaned slightly at times. On arrival at the hut his clothes were cut off and he was dried and wrapped in dry clothes and a blanket. His legs and arms were rubbed in an attempt to restore circulation. One and a quarter hours after arrival at the hut his pulse could not be felt and artificial respiration was applied for two hours without success. Death was certified as due to exhaustion and exposure followed by cardiac arrest.

Case 2

This man progressively collapsed from exposure. He was assisted by members of his party for approximately one hour, covering one mile downhill before he was unable to go any further. When a stretcher party arrived shortly thereafter he appeared to be unconscious. He was carried a quarter of a mile downhill on a Thomas stretcher to a well-heated shelter. On the stretcher he made moaning noises. In the shelter his wet clothes were removed and a warm sleeping bag and hot water bottles put around him. Shortly afterwards he had a fit and ten minutes later his breathing and pulse stopped. Artificial respiration was continued until a doctor arrived and certified that he was dead. Approximately one hour passed between arrival at the shelter and certification of death.

Case 3

This unusually powerfully built man fractured his right ribs 4–10 posteriorly in an avalanche. The eighth rib lacerated the mid-zone of the lung with underlying intrapulmonary haemorrhage, collapse of the lower lobe and a one-pint haemothorax. There was also complete separation of the pubis with a large intraparietal haematoma and an internal laceration of the liver. There was no significant head injury (post mortem).

Shortly after the accident he regained consciousness and his companions made a snow hole for him. Approximately six and a half hours later a rescue party arrived at which time he was still conscious. He was carried three miles on a mountain rescue stretcher and then three and a half miles by Land Rover, the total journey lasting three hours. On arrival the local doctor found that he was still alive but very weak and gave him an injection of Coramine. Ten minutes later he died. Death was considered to be caused by haemorrhagic shock (post mortem).

Case 4

This man fell 600 feet in a snow- and ice-filled gully. He was breathing despite major head injuries when put on to a stretcher by local climbers. After a short distance the party was met by the mountain rescue team and an accompanying doctor found that he was dead. Death was certified as due to a fractured base of skull.

Case 5

This man fell 400 feet down a snow slope on to scree at 3.20 pm. When found he was unconscious. At 4.30 pm local climbers began moving him by stretcher. After more than a mile he was transferred, still on the same stretcher, to a tracked snow tractor. After a further three miles he stopped breathing at 8.00 pm, 100 yards from a waiting ambulance. A doctor in the ambulance certified death due to a fractured skull.

The ten deaths in hospital all occurred some time after admission. No evidence was found of the journey contributing to these later deaths.

DISCUSSION

Only five of 175 mountaineering deaths occurred during the stretcher journey, while 200 patients, many of them seriously ill, were carried down alive. Two of the five deaths in transit were due to exposure, three to injuries.

In the two deaths from exposure the patients' condition appears to have worsened during the stretcher journey. The delay in starting treatment might have been avoided by setting up a tent and allowing the casualties to warm up before moving them (Pugh, 1966). Such a course presupposes that the team can provide adequate shelter and warmth for both casualty and team members in extreme conditions of terrain and climate, and can exclude injuries requiring hospital treatment. Such logistics and responsibility are not always practicable. A more recent alternative is the use of improved casualty bags with much better insulation. No deaths in transit from exposure have occurred since the introduction of these bags, which undoubtedly helped the forty exposure victims carried down alive.

Table I.—Deaths on Scottish mountains (1960–1972)

Total call-outs (Includes false alarms, searches, crag-fast, minor injuries and illness)	715
Patients carried down alive (Injury 80%, collapse 20%)	200
Deaths (injury 80%, collapse 20%)	
At scene of collapse or injury	160
On stretcher	5
In hospital	10
Total deaths	175
(Aircraft crashes excluded)	

Of the three deaths from injury, only in case 3 did death appear to be due to blood loss from injuries which, with prompt hospitalization, might not have been fatal. The time sequence suggests that bleeding may have been restarted by the movement of either the stretcher or the vehicular journey. The combination of chest and pelvic injuries is uncommon in mountaineering but similar road-accident victims may be particularly susceptible to ill effects from ambulance transport (Waddell et al., 1975). Climbers with serious trunk injuries may be especially suitable for helicopter evacuation when this is feasible. In the two deaths from head injuries there is no evidence that the journey was harmful. One hundred and fifty patients with injuries, many of them serious, were carried down alive.

These results compare favourably with ambulance transport after road accidents. In a similar review of rural road accident deaths in Australia, Adams (1967) found that 63 per cent of 126 deaths occurred at the scene of the accident, 10 per cent in the ambulance and 27 per cent in hospital.

Table I supports the view (Campbell, 1972; Editorial, 1972) that, were doctors to accompany mountain rescue teams, they would be unlikely to produce a significant improvement in the mortality statistics. Any major improvement is likely to depend on reaching ill or injured mountaineers more rapidly as 90 per cent of deaths occur before the arrival of the mountain rescue team. In addition a greater willingness by exposure victims to stop and seek shelter would retard the cooling process while awaiting the arrival of the team. (Longland et al., 1964).

Detailed medical observations during the stretcher journey would be necessary to prove conclusively that movement caused no harm. Death during or as a result of the journey is but a crude index of the gravest effects. Nevertheless this review, despite its inherent limitations, has shown surprisingly little evidence of harm from mountain rescue transport. With 200 patients carried down alive, only five died during the journey and ten later in hospital. The most critically ill patients die before help arrives. Those who survive this initial period generally appear able to withstand the unavoidable journey to hospital.

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This report is dedicated to the men of the Scottish mountain rescue teams, many of whom generously helped by providing information. The Crown Office kindly made available their records.

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Effects of Ambulance Transport in Critically Ill Patients

G. WADDELL, P. D. R. SCOTT, N. W. LEES, I. MCA. LEDINGHAM

Summary

Two groups of critically ill patients were transferred by ambulance from other hospitals to a central intensive therapy unit. The effect of transport was reviewed retrospectively in 46 patients and prospectively in 20 patients. Of the 46 patients reviewed retrospectively six became hypotensive, six became hypertensive, and seven developed delayed hypotension. One patient developed fits and six out of 13 patients had a rise in arterial $P\text{CO}_2$ of 1·6-4·1 kPa (12-31 mm Hg).

Of the 20 patients reviewed prospectively, one patient became hypertensive due to overtransfusion, one had a fit, but none became hypotensive. Three out of four cases of delayed hypotension were related to starting intermittent positive pressure ventilation. Arterial $P\text{CO}_2$ fell in one patient and arterial $P\text{CO}_2$ rose in two, each change being related to changed oxygen therapy or narcotics. There were no changes in other cardiovascular or respiratory indices, body temperature, or urine production.

Earlier transfer, resuscitation before transfer, continuing medical care during the journey, and hence a slower smoother journey seemed to be important factors in the management of these patients. Our findings may have important implications in the future regional organization of the care of critically ill patients.

Introduction

With categorization of hospitals and increasing specialization transfer of critically ill patients between hospitals is likely to become more frequent. Thus detailed knowledge of the effects of transport is essential.

Most previous studies have dealt with primary evacuation of patients in an unstable condition from roadside or home.[1-3] Isolated instances of collapse seem to have been related to sudden jolting of the ambulance,[3 4 5] but the lack of any pretransfer baseline data makes conclusions difficult. Secondary evacuation between hospitals of selected groups of ill patients is reported in several French studies.[6-10] Serious collapse, arrhythmias, cardiac arrest, acute respiratory insufficiency, or fits occurred in 5% of such patients, and 15-30% developed mild hypotension. These reports, however, were generally retrospective clinical studies and gave few objective data.

Retrospective Review

In six years 67 patients were transferred by ambulance from other hospitals to the intensive therapy unit of the Western Infirmary, Glasgow. Adequate records were available on 46.

The primary clinical conditions for which transfer was deemed necessary are indicated in table I. Though there were no statistically significant changes in mean heart rate or systolic blood pressure as a result of the journey considerable variation in haemodynamic response occurred from patient to patient. Twenty-seven patients had no change in heart rate or systolic blood pressure. In six patients a raised systolic blood pressure of 30-50 mm Hg occurred which settled spontaneously in two to four hours (fig. 1). In six patients a fall in blood pressure of more than 40 mm Hg occurred. Since urgent treatment was required to correct this hypotension spontaneous recovery could not be assessed (fig. 2). A delayed fall in systolic blood pressure of 20-30 mm Hg occurred one to one and a half hours after transfer in seven patients (fig. 3), possibly related to a change in treatment after arrival at the intensive therapy unit. One previously stable patient developed fits and tachycardia 14 minutes after the journey. The distribution of these patterns of response within the series is shown in table I. Septic shock seemed particularly likely to be associated with either hypertension or hypotension, and patients with chest injuries seemed more likely to develop hypertension.

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TABLE I—*Primary Condition and Cardiovascular Response to Ambulance Journey in Two Study Groups. Results are Numbers of Patients*

Primary Condition	Retrospective Study (n = 46)				Flying-squad Study (n = 20)			
	No Change	Hypertension	Hypotension	Delayed Hypotension	No Change	Hypertension	Hypotension	Delayed Hypotension
Cardiac Shock	4	0	0	1	1	0	0	0
Haemorrhagic Shock	2	0	1	1	3	0	0	0
Septic Shock	3	2	3	0	5	1	0	1
Respiratory failure	7	0	2	1	4	0	0	2
Chest injury	5	4	0	1	0	0	0	0
Coma	5	0	0	2	1	0	0	1
Renal failure	1	0	0	1	1	0	0	0
Total	27	6	6	7	15	1	0	4

In the 13 patients for whom complete data were available there were no statistically significant changes in mean respiratory rate or arterial blood gases (table II), but six of the patients had a rise in arterial $P\text{CO}_2$ of 1·6-4·1 kPa (12-31 mm Hg). In 28 patients with temperature readings mean oral temperature before transfer was 36·5°C and mean rectal temperaure after transfer was 36·8°C. Patients whose temperature was 36·1°C or less had a higher incidence of immediate cardiovascular response to the journey, but this was not statistically significant. No other pretransfer index was of any prognostic value.

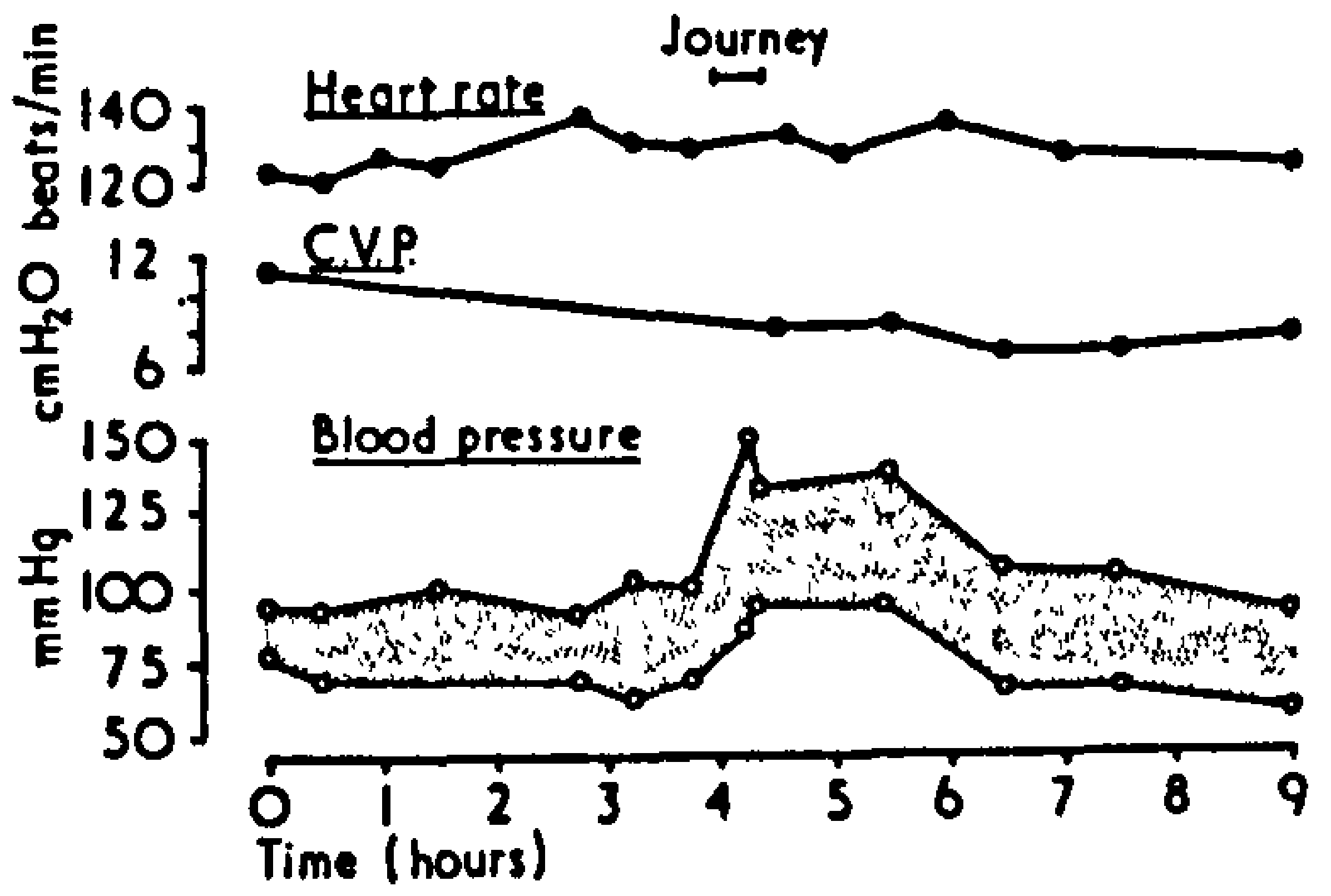

FIG. 1—Retrospective study. One patient's hypertensive response to ambulance journey.

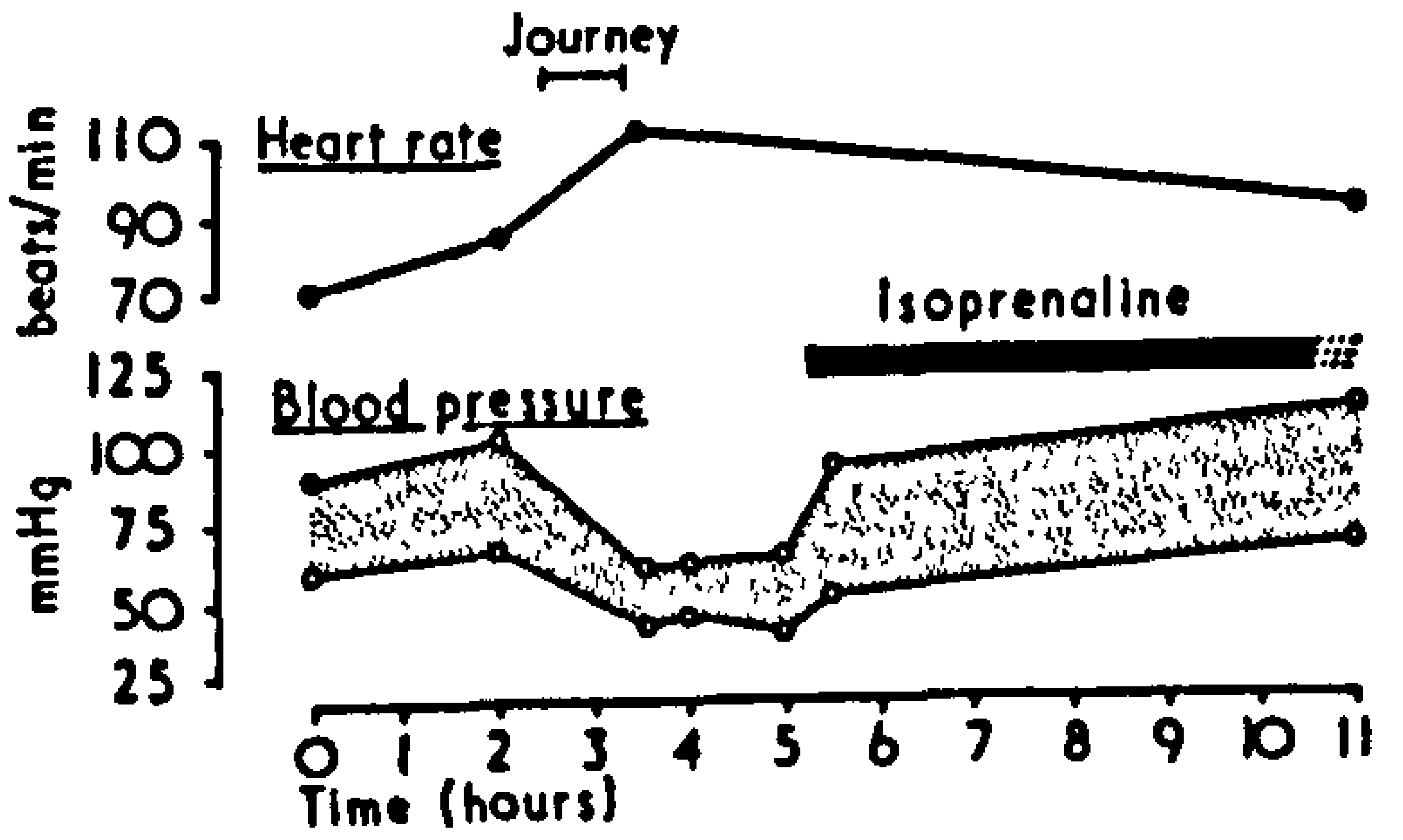

FIG. 2—Retrospective study. One patient's hypotensive response to ambulance journey.

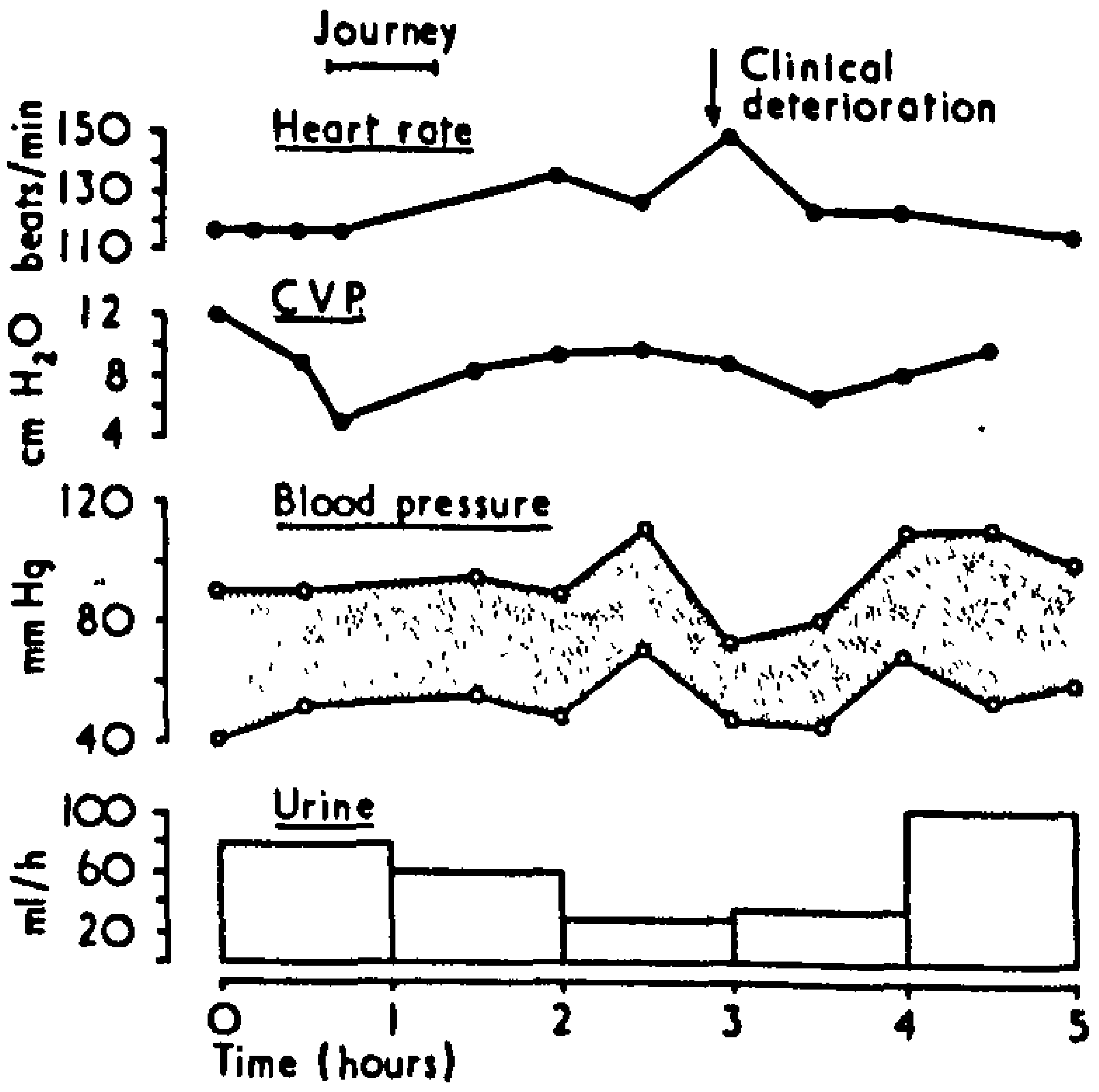

FIG. 3—Retrospective study. One patient's delayed hypotensive response to ambulance journey.

No deaths occurred within 20 hours of the journey. The final mortality of transferred patients was comparable to that of similar patients treated in the unit who had initially been admitted to the Western Infirmary. The mortality in patients who developed hypertension (67%) or hypotension (50%) was significantly higher ($P < 0.05$) than in patients with no change (31%) or delayed hypotension (29%). This may simply mean that more severely ill patients are more likely to show an immediate cardiovascular response to the journey.

Prospective Study

The intensive therapy unit "flying squad" consisted of one or two members of a previously described "shock team."[11] When the intensive therapy unit received a request for a transfer the flying squad travelled to the referring hospital, set up monitoring equipment, and began treatment. They accompanied the patient in an ambulance of standard design and continued treatment on arrival at the unit.

Readings of heart rate, blood pressure, central venous pressure (C.V.P.), toe temperature, and respiratory rate were made every quarter of an hour for one hour before the journey, in the ambulance at the start and finish of the journey, and for two hours thereafter. Heart rate was measured by palpation of the pulse or counting from the E.E.G. Blood pressure was measured by arm cuff, mercury manometer, and auscultation. C.V.P. was measured by a saline manometer connected to a central venous catheter whose position was confirmed by chest *x*-ray examination. The zero reference was the mid-axillary line in the fifth interspace. Toe temperature was measured by a Grant thermometer with a small thermistor taped to the big toe (accuracy ± 0·3°C). Respiratory rate was counted.

Rectal temperature was recorded on the Grant thermometer using a rectal thermistor taped in position (accuracy ± 0·3°C). Readings were made one hour before, immediately before, immediately after, and one and two hours after the journey. A 20-second, lead-II E.C.G. was recorded at the same intervals on a portable battery-operated recorder (Transite II). The bladder was catheterized and emptied and urine production measured over the hour before transfer, the period of the journey, and two hours afterwards. Fluid transfused was recorded over the same periods.

A 2-ml heparinized sample of arterial blood was taken by radial stab immediately before the journey. The syringe was sealed with a plastic cup and stored in a vacuum flask containing ice and water. A second sample was taken immediately after the journey. Blood gases on the two samples were measured using standard apparatus (Radiometer system). Preliminary experiments showed that storage in this manner for up to two hours did not introduce clinically significant errors in pH, $P\text{CO}_2$, or $P\text{O}_2$.

Two groups of patients were studied prospectively—21 critically ill patients transferred from other hospitals to the intensive therapy unit of the Western Infirmary, Glasgow, and 20 convalescent surgical patients.

In the first group one patient was considered unsuitable for transfer—after ventricular fibrillation during tonsillectomy. She was unresponsive to pain, had fixed dilated pupils, no spontaneous respiration, a systolic blood pressure of 40-50 mm Hg, a bizarre E.C.G., and a rectal temperature of 35°C. She died within 30 minutes of this decision. The clinical conditions in the 20 patients who were transferred were comparable to those of patients in the retrospective study except that there were no chest injuries. Fifteen patients were transported two miles and five from four and a half to 13 miles. The average ambulance ride was 12 minutes and the total time from bed to bed 33 minutes.

The 20 convalescent surgical patients were studied over the same two-mile distance as that covered by the 15 patients of the first group. Similar but non-invasive measurements were made of heart rate, blood pressure, E.C.G., respiratory rate, and rectal and toe temperatures.

TABLE II—*Mean Respiratory Rate and Arterial Blood Gases Before and After Transfer in Two Study Groups*

	Retrospective Study (n = 13)		Flying-squad Study (n = 20)	
	Before Transfer	After Transfer	Before Transfer	After Transfer
Respiratory rate/min	33	30	26	28
pH	7·35	7·35	7·35	7·39
P_{CO_2} (kPa)	6·1	6·9	5·5	5·5
P_{O_2} (kPa)	8·0	8·7	13·6	12·9
Base excess (mmol/l)	−2	0	−2	−1

Conversion: SI to traditional Units
Blood gases: 1 kPa W 7·5 mm Hg.
Base excess: 1 mmol/l = 1 mEq/l.

Results

The 20 convalescent surgical patients did not show clinically significant changes in any variable, either individually or mean.

There was no change in the mean cardiovascular values of the 20 critically ill patients transferred (fig. 4). Unlike the patients in the retrospective survey, variations in haemodynamic response from patient to patient in the prospective study were minimal. In no patient did the E.C.G. pattern alter. One patient became hypertensive but the blood pressure had begun to rise before the journey, and the rise seemed to result from an intravenous infusion of plasma and mannitol. No patient became hypotensive. Four patients developed delayed hypotension similar to that described previously (see fig. 3), but in three this was related to starting intermittent positive pressure ventilation (I.P.P.V.).

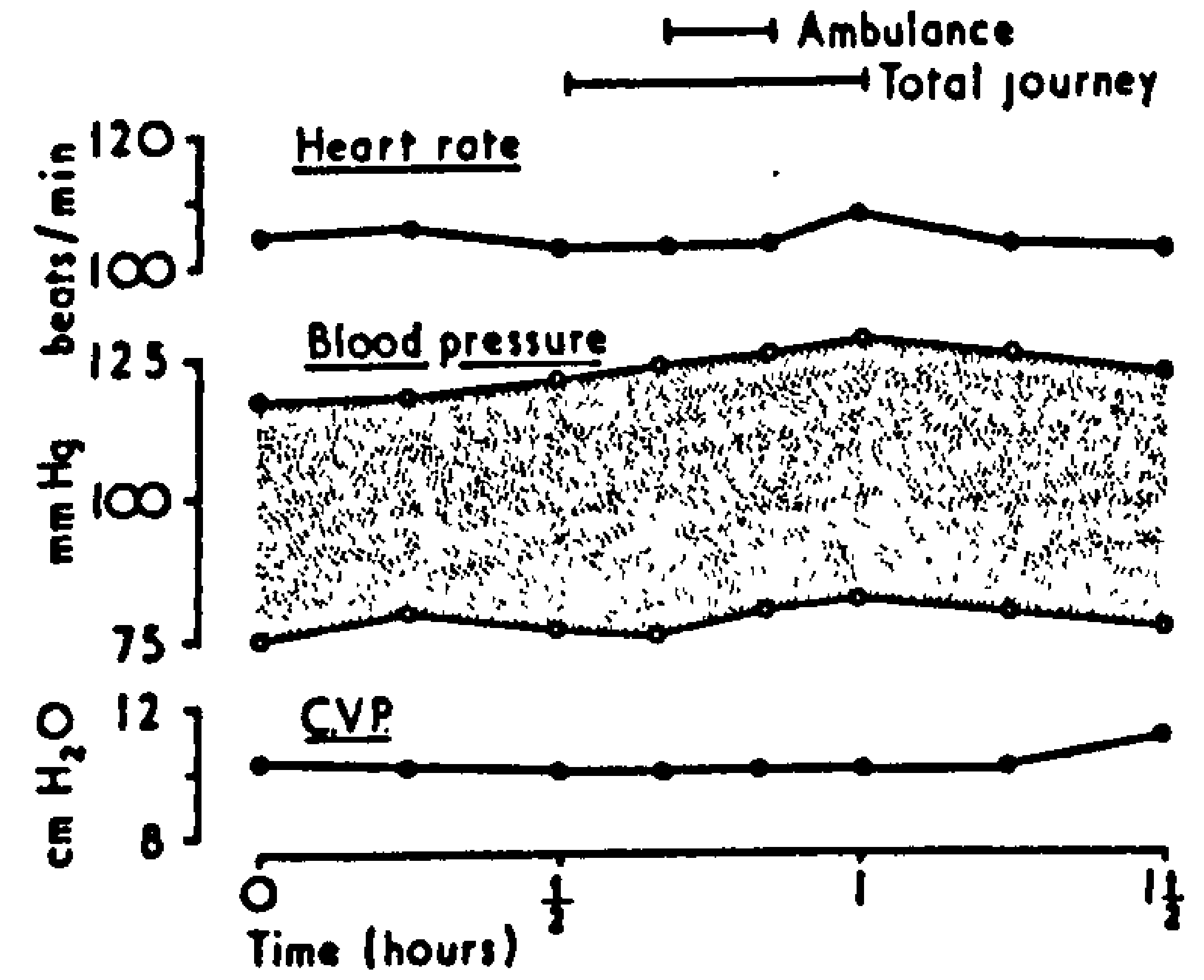

FIG. 4—Prospective study. Mean cardiovascular values of 20 critically ill patients.

There was no change in mean respiratory rate or arterial blood gases in the critically ill patients (table II). P_{O_2} fell in one patient, and P_{CO_2} rose in two, apparently because of withdrawal of oxygen therapy during the journey or the use of intravenous morphine.

Transfusion requirements slowly diminished with progressive resuscitation (fig. 5), the rate being uninfluenced by the journey. Urine production slowly increased, again uninfluenced by the journey.

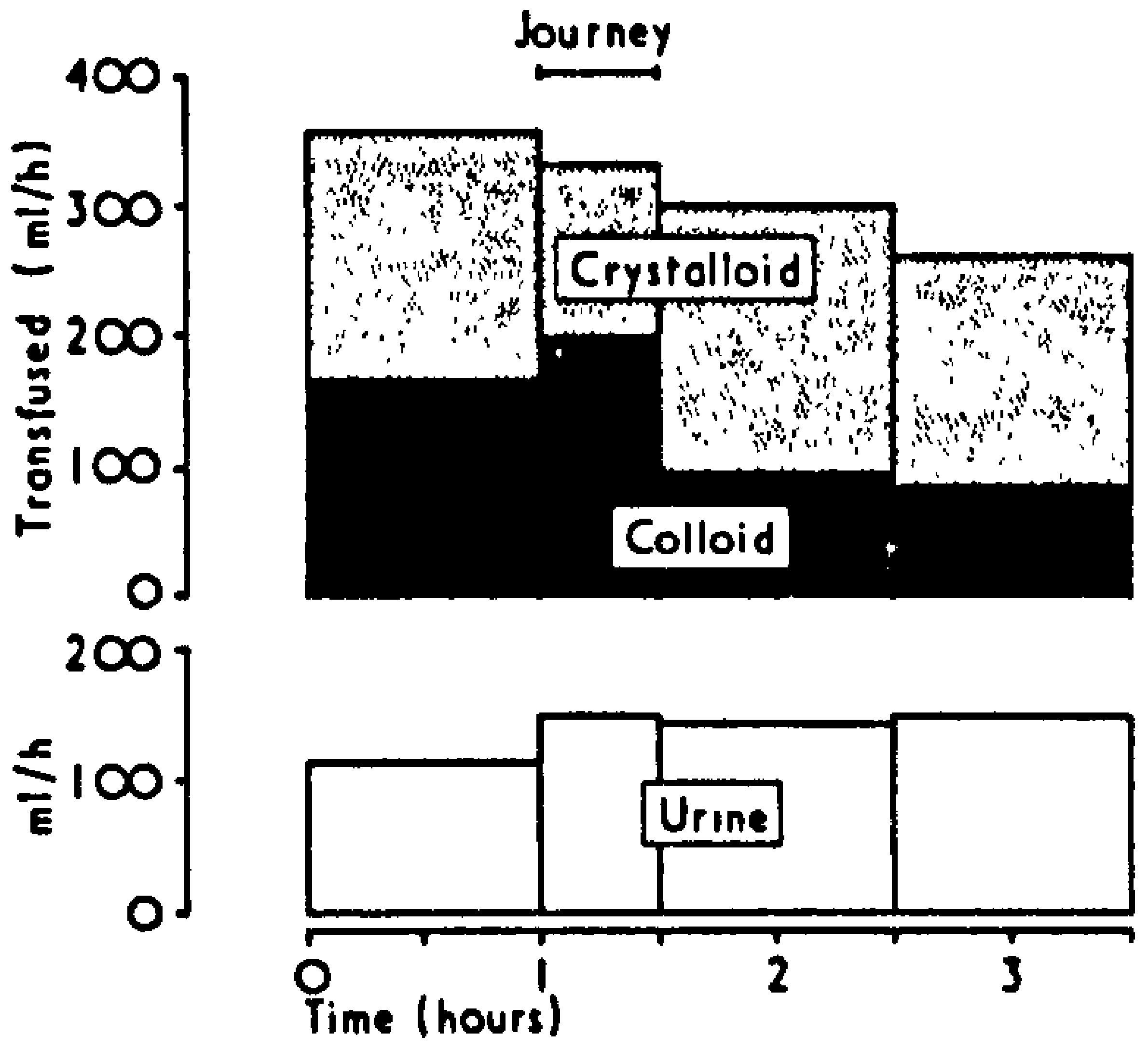

FIG. 5—Prospective study. Mean fluid balance of critically ill patients.

There was no change in mean rectal temperature in either the critically ill or the convalescent surgical group (fig. 6). No patient had a change of more than 0·5°C. Both the critically ill and convalescent surgical groups had a comparable slight fall in toe temperature. Ambient temperature is also illustrated, the sharp falls corresponding to the moves to and from the ambulance.

One patient with a post-partum intracerebral haemorrhage had a fit 15 seconds after the ambulance moved off. Fits had been controlled with muscle relaxants and I.P.P.V. for the previous three hours.

A general comparison of the critically ill patients in the retrospective and prospective series is made in table III.

TABLE III—*Comparison of Retrospective and Flying-squad Patients*

	Retrospective Study	Flying-squad Study
Number of patients	46	20
Mean age (years)	42	57
Percentage of men	61	65
Percentage with pretransfer systolic blood pressure < 100 mm Hg	28	40
Percentage on I.P.P.V. before transfer ..	22	10
Percentage of deaths within 24 hours of transfer	6·5	5
Final mortality (%)	39	45

Discussion

The effect of an ambulance journey may be either direct or indirect.[5] Discomfort, pain, and other stimuli may directly affect the patient's condition while lack of facilities and the motion of the ambulance may reduce the ability of the attendants to provide treatment.

In our retrospective study the incidence of major cardiovascular changes was comparable to that reported by other authors dealing with similar patients.[6 8] No previous reports, however, have been made of hypertension or delayed hypotension though the former seems a natural response to the stress of transport. Delayed hypotension, though not strictly an effect of transport, can be regarded as a consequence of transfer to a different unit. The high incidence (46%) of a raised arterial P_{CO_2} after transport confirms the difficulty in assessing and

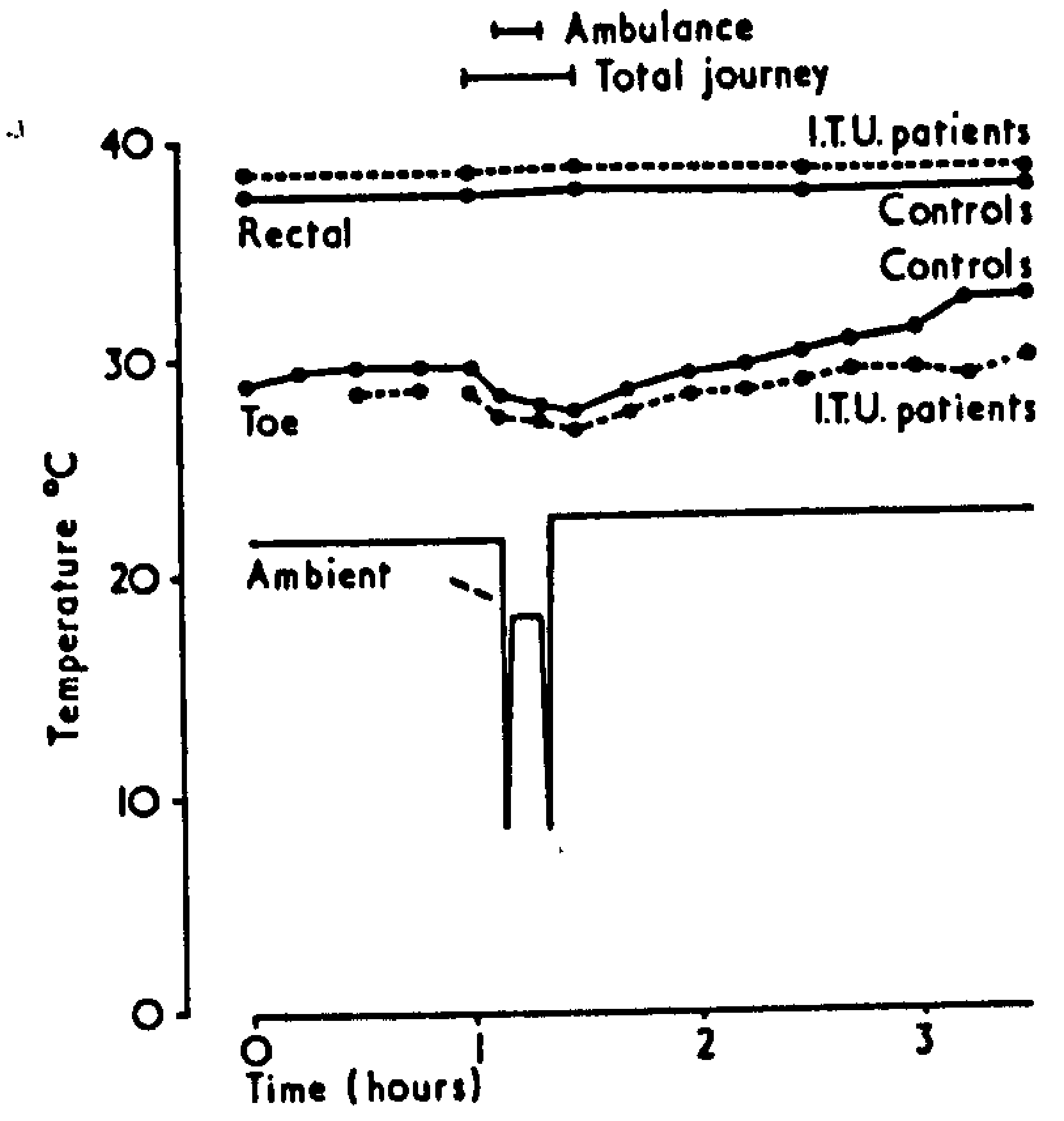

FIG. 6—Prospective study. Mean rectal and toe temperatures of 20 critically ill intensive therapy unit (I.T.U.) and 20 convalescent surgical patients (controls).

maintaining inspired oxygen and ventilatory requirements under these circumstances. The occurrence of fits has been noted previously.[5, 7]

In the prospective study there was a marked reduction in the number of patients who became hypertensive, and none became acutely hypotensive. Three of the four cases of delayed hypotension were related to beginning I.P.P.V. shortly after the patient reached the intensive therapy unit. All the instances of altered blood gases were related to changes in oxygen therapy or the administration of narcotics. The fit seemed to be a direct consequence of ambulance movement. It was rapidly controlled but might have been prevented by increased sedation before transfer, as shown by Poisvert.[7] The slight fall in great toe temperature suggested mild peripheral vasocontriction,[12] but the clinical significance of this observation is difficult to ascertain when ambient temperature is changing. All these effects, though potentially harmful, subsided either spontaneously or promptly in response to treatment. Thus, the 20 critically ill patients in the prospective study showed less frequent and less serious effects of the journey than those studied retrospectively. Most of the minor effects could be accounted for by changes in treatment during the journey or after arrival at the intensive therapy unit; evidence for the direct stress effects of the journey itself was minimal.

Several changes in procedure for the transfer of critically ill patients were introduced at the start of the prospective study. These included careful resuscitation before transfer, continuing medical care during the journey, and a slow gentle journey. The relative importance of each of these factors is uncertain but it is clear that their combined effect prevented the occurrence of serious complications in this group of seriously ill patients. The value of an experienced and properly equipped intensive therapy flying suuad seems obvious. More detailed investigation of the in-transit phase of the ambulance journey and of journeys from more distant hospitals is in progress.

We are indebted to the medical and nursing staff of the intensive therapy unit, Western Infirmary, Glasgow, and the referring hospitals. The cardiology department of the Western Infirmary and the physiology department of Glasgow University kindly lent equipment. The ambulance and portering staff, especially at the Western Infirmary and Gartnavel General Hospital, Glasgow, were unfailingly helpful and patient.

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Movement of Critically Ill Patients Within Hospital

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Summary

Critically ill patients were observed during routine movement inside the hospital to and from the intensive therapy unit. One patient a month suffered major cardiorespiratory collapse or death as a direct result of movement. Renewed bleeding of a pelvic fracture, cardiac arrhythmia, cardiac embarrassment due to a haemothorax, and cardiovascular decompensation were seen. It was difficult to continue treatment during movement, especially maintaining an airway or providing adequate intermittent positive pressure ventilation. Seventy postoperative patients suffered few ill effects on being moved.

Greater awareness of the dangers of moving critically ill patients within hospital is needed. Thorough preparation for the move and adequate maintenance of treatment during movement requires the skill of experienced medical staff.

Introduction

Recently there has been much interest in the effects of ambulance transport,[1-5] yet there is little information on the effect of moving critically ill patients within hospital. Taylor *et al.* electrocardiographically (E.C.G.) monitored high-risk cardiac patients moved within hospital and found that 90% had a rise in heart rate and two out of 50 seemed to develop arrhythmias in response to movement.[6] In 11 out of 22 patients moved from theatre to an intensive therapy unit (I.T.U.) after cardiopulmonary bypass blood pressure rose transiently while in three it fell by up to 15 mm Hg. There was a variable change in heart rate and no appreciable change in E.C.G.[7]

I report here a prospective clinical study of the effect of moving critically ill patients to and from the I.T.U. of the Western Infirmary, Glasgow (study 1), and a supplementary study on the effects of moving routine postoperative patients back to the ward (study 2).

Study 1

PATIENTS AND METHODS

In the five-month study 55 patients were admitted to the five-bed I.T.U. of the Western Infirmary, Glasgow. The unit has a particular interest in shock and respiratory failure, and there are separate units for coronary care, renal dialysis, and burns. No neurosurgery or cardiopulmonary bypass is performed in the hospital. Normal postoperative care is carried out in separate recovery rooms.

The 55 patients had 86 moves to or from the referring units or theatre during the acute phase of their illness. All moves were carried out routinely by the medical and nursing staff of the I.T.U. In 33 moves of the 20 most ill patients detailed clinical observations were made before, during, and after the move. No special measures were taken and so far as possible the observations did not interfere with the routine execution of the move. Baseline readings for an average of 30 minutes before movement allowed patients to act as their own controls.

RESULTS

Significant changes during and after movement were seen in seven patients, each of whom had been stable before movement (table I). These changes seemed to have been caused by the movement; the cardiovascular changes, transfusion requirements, and fall in haemoglobin from 12 to 6 g/dl seen in case 1 (fig. 1) were consistent with movement having caused renewed bleeding. Fig. 2 shows the recordings in case 2, and fig. 3 gives a sample of the E.C.G. before and after movement. Fig. 4 shows the blood pressure in case 5.

TABLE I—Study 1. *Effects of Movement within Hospital on Critically Ill Patients in Five Months*

Case No.	Age and Sex	Diagnosis	Move	Effect
1	11 M.	Fractured pelvis ..	Theatre to I.T.U.	Rebled, died
2	54 M.	Congestive cardiac failure, pulmonary emboli	Ward to I.T.U.	Atrial fibrillation, hypotension
3	56 M.	Mediastinal haemorrhage	Resuscitation room to ambulance	Airway obstruction
4	67 M.	Bleeding aortic aneurysm	Theatre to I.T.U.	Hypertension
5	46 F.	Right haemothorax ..	Rolled on to left side	Hypotension
6	91 M.	Pulmonary embolus ..	Ward to I.T.U.	Hypotension, died
7	38 M.	Crushed chest, haemothorax	I.T.U. to theatre	Cardiac arrest, died

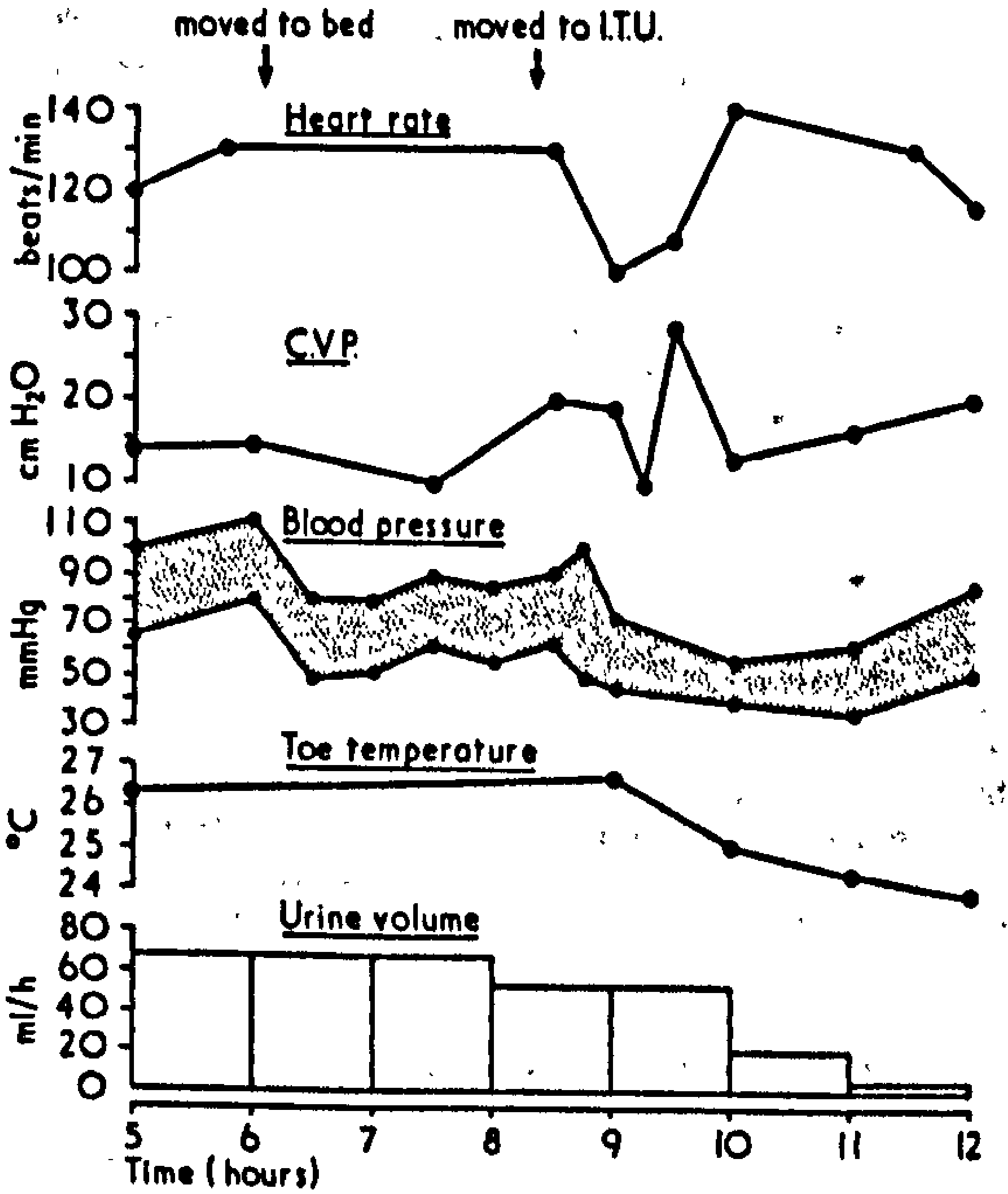

FIG. 1—Case 1. Recordings when moved from theatre to I.T.U. Patient had lain undisturbed on operating table for six hours after the end of an operation for pelvic bleeding.

During the baseline period only one patient showed progressive terminal hypotension and no other cases of sudden collapse or cardiac arrest were observed. Two patients had a transient fall in

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systolic blood pressure to 70-75 mm Hg, and another two showed a rise of 30-50 mm Hg, all related to changes in artificial ventilation. One patient showed spontaneous reversion from supraventricular tachycardia to sinus rhythm.

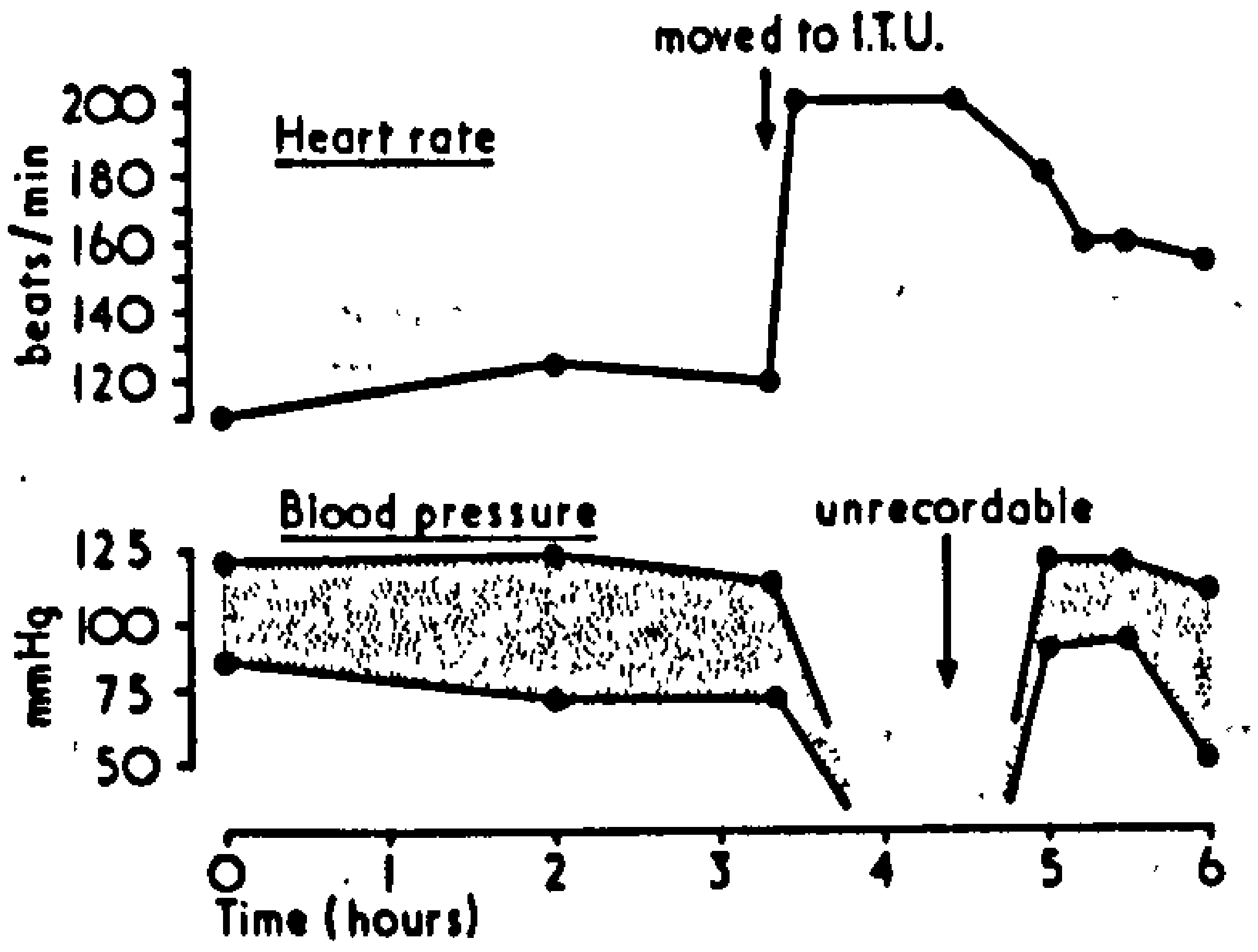

FIG. 2—Case 2. Cardiovascular recordings in patient with cardiac failure and pulmonary emboli moved from ward to I.T.U.

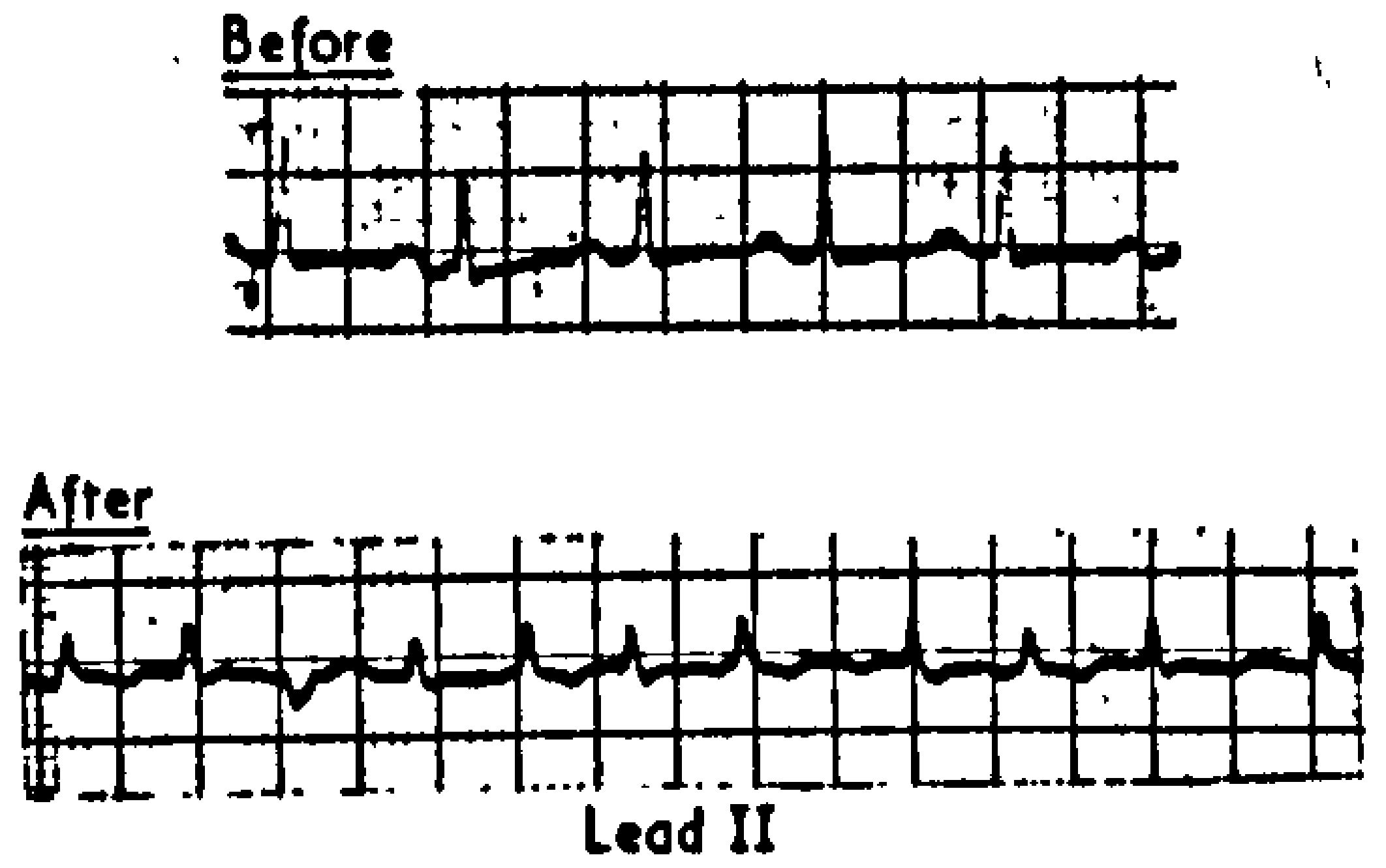

FIG. 3—Case 2. E.C.G. 30 minutes before and 15 minutes after movement.

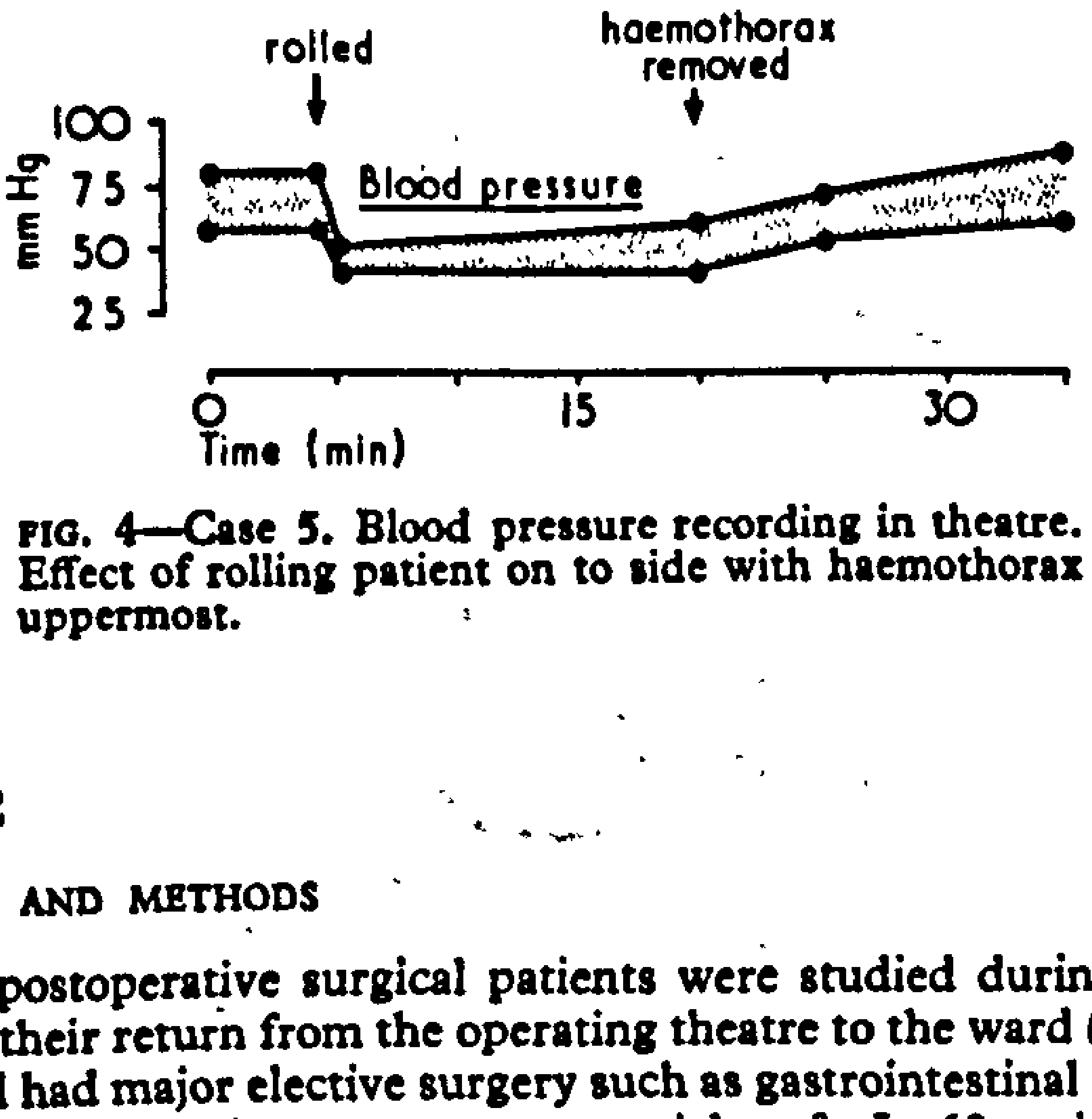

FIG. 4—Case 5. Blood pressure recording in theatre. Effect of rolling patient on to side with haemothorax uppermost.

Study 2

PATIENTS AND METHODS

Seventy postoperative surgical patients were studied during various stages of their return from the operating theatre to the ward (table II). Most had had major elective surgery such as gastrointestinal resection, joint replacement, thoracotomy, or arterial graft. In 60 patients three clinical readings of heart rate and blood pressure—the last immediately before movement—confirmed stability before movement. Readings were repeated immediately after they had been moved and 5, 15, and 30 minutes after. All readings were made by one observer who did not interfere with the usual routine of the staff executing the move.

In 10 patients blood pressure was recorded by a radial artery catheter, capacitance transducer (Elema Schonander EMT 35), and an Elema Schonander ink-writing recorder (Mingograph 81). After baseline readings at the end of the operation a continuous record was made while the patient was lifted by stretcher from the operating table to a trolley.

RESULTS

All patients were stable during the baseline period, and mean heart rate and blood pressure remained stable. In the 60 patients with clinical readings mean heart rates immediately before and after movement were 89/min and 91/min respectively. The corresponding blood pressure readings were 127/74 mm Hg and 128/73 mm Hg. None of the intra-arterial recordings showed any significant change. Three patients had a rise in heart rate of 24-40/min. Systolic blood pressure rose 15-20 mm Hg in two patients and fell 14 mm Hg in one. Heart rate and blood pressure returned to previous levels within five minutes of stopping movement. No other patient had a rise or fall in heart rate of more than 12/min or in blood pressure of more than 10 mm Hg. Two patients vomited, one while being wheeled to the ward in bed, the other two minutes after being lifted from trolley to bed in the recovery room. In one patient a suction drain caught in a doorway and was disconnected.

Discussion

In study 1 about one critically ill patient a month suffered major cardiorespiratory collapse or death as a result of movement within hospital. Though similar incidents occur in other hospitals,[8 9] this was a surprisingly high incidence. So far as possible the study reflected normal routine in this hospital. Any unintentional influence the observer might have had would probably have improved standards, so this incidence will tend to be an underestimate rather than an overestimate.

Many of these patients might have died anyway, even though only one patient progressively deteriorated and died during the control period. Baseline readings showed that most patients were relatively stable, and the changes seen seemed to be a direct result of movement. The mechanisms were varied: in case 1 movement of a major fracture caused renewed bleeding[8 10]; in case 2 movement seemed to precipitate cardiac arrhythmia[6 11 12]; in case 5 the haemothorax seemed to cause direct pressure on the heart or great veins when the patient was rolled on to her side; and in cases 1 and 6 movement may have precipitated cardiovascular decompensation with a fall in blood pressure and a rise in central venous pressure (C.V.P.). The frequency of collapse in patients with intrathoracic bleeding (cases 3, 5, and 7) supports the observation that patients with major chest injuries are particularly vulnerable to movement.[6]

The effects of movement may be direct or indirect[8]: discomfort, pain, and the physical stimuli of movement may directly affect the patient's condition while lack of facilities and the limitations of movement may reduce the ability of attendants to provide continuing life support. Such indirect effects were clearly illustrated by the difficulty of maintaining an airway (case 3) or intermittent positive pressure ventilation (cases 4

TABLE II—Study 2. *Details of Postoperative Patients Moved within Hospital*

Type of Surgery	No. of Patients	Mean Age (years)	No. of Men	Mean Time from Operation (h)	Movement			Mean Duration of Movement (min)
					Lifted on/off Trolley	Moved to Ward	Lift between Floors	
General (Western Infirmary)	20	55	10	2·8		+		2
General and thoracic (Gartnavel Hospital)	10	47	5	1·5	+	+	+	4·75
Paediatric	10	8	6	0·25	+	+	+	2
Orthopaedic	20	57	5	2	+	+	+	3·25
Vascular	10	59	8	0·1	+*			3 seconds

* Intravascular recording of blood pressure.

and 7). Even such simple measures as traction for a fracture (case 1) or a suction drain (study 2) can easily be disturbed while moving along narrow corridors or into lifts.

The incidence of serious effects due to intrahospital movement in critically ill patients (study 1) was much higher than that previously seen during ambulance transport of similar patients.[5] This may be partly due to a willingness to move patients within hospital who would be considered too moribund to subject to an ambulance journey. It is probably due also to less thorough preparation and less adequate maintenance of treatment during movement. In the ambulance study every possible care was taken to stabilize the patient and then maintain treatment throughout the journey. When simply wheeling a patient along a corridor it is tempting to imagine that there is less opportunity for misfortune and that a few minutes gap in treatment will do no harm. The results of study 1 suggest that in critically ill patients this is untrue; their movement within hospital may be as hazardous as an ambulance journey, and it should be seriously considered whether they need to be moved at all. Adequate preparation is essential and every possible care should be taken to maintain treatment and forestall "accidents" during the move. Such patients should not be consigned to the care of non-medical or inexperienced staff.

Experience of both ambulance transport and moving patients within hospital suggested that patients recovering from a recent operation and anaesthetic more often showed cardiovascular effects of movement, but the results of study 2 provide no evidence to support this hypothesis, all 70 patients showing remarkable stability. Weller also observed only minor effects of moving patients after cardiopulmonary bypass.[7] Only two of the seven very ill patients affected by movement (study 1) were recovering from an operation. Provided adequate care is taken postoperative patients do not seem to be particularly vulnerable to movement.

I thank Dr. I. McA. Ledingham, consultant clinical physiologist, Western Infirmary, Glasgow, for his advice, encouragement, and help in organizing this study. The staff of the shock team and the I.T.U. helped greatly in the collection of data on the critically ill patients. In study 2 the recovery room staff, porters, and ward staff of the Western Infirmary, Gartnavel General Hospital, and the Royal Hospital for Sick Children, Glasgow, were unfailingly patient and helpful. Drs. G. Smith and D. Proctor, consultant anaesthetists, and Mr. J. Airnes, chief physics technician, kindly set up the intra-arterial recordings.

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Cardiovascular effects of movement in hemorrhagic shock dogs

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This study was designed to observe the effect of movement on ill, injured, or shocked animals. Lightly-anesthetized dogs were subjected to hemorrhagic shock. Ambulance transport was simulated by shaking, jolting, and rocking a table in three axes as well as lifting and dropping it. Accelerometer readings compared well with previously reported readings in ambulances. Simulated transport caused a rise in blood pressure and cardiac output in five of the six dogs, with no change in heart rate or right atrial pressure. A 15° head-up tilt caused a marked fall in blood pressure and cardiac output in two of the six dogs, leading to asystole in one. This could be related to diminished venous return from the lower body. Intermittent positive pressure ventilation had no protective action. *(Key words: movement, transport, tilting, hemorrhagic shock, asystole, hypotension, cardiac output, IPPV.)*

Several investigators have noted severe hypotension, arrhythmias, and cardiac arrest during ambulance journeys, often related to sudden jolting.[1-4]

Limited experimental studies of healthy, supine human subjects on vibration tables suggest that vibration causes a rise in heart rate (HR) and cardiac output (CO).[5,6] Variable effects of vibration on blood pressure (BP) have been reported: hypertension by Hood et al[6]; hypotension or occasional hypertension by Pichard et al.[3]

The uncertainty may be partially due to the considerable difficulties in eliminating vibration and artifacts from intravascular pressure recordings.[7,8] Accelerometer readings of various frequencies of vibrations at the X, Y, and Z axes *(Fig. 1)* tend to eliminate artifacts inherent in one axis, single frequency, constant amplitude vibrations.

Hood and associates[6] found a close similarity in the cardiovascular response of unsedated supine humans and anesthetized dogs to low frequency X-axis vibration. HR and CO consistently rise, while BP appears to fall initially with a sustained and steady rise after the first minute of vibration.[6-9] No reported studies could be found of the effect of any type of movement on ill, injured, or shocked animals.

Cullen et al[2] reported their clinical impression that head-up tilt of ill or shocked patients can be harmful. Pugh,[10] reviewing mountaineering hypothermia, found suggestive evidence that head-

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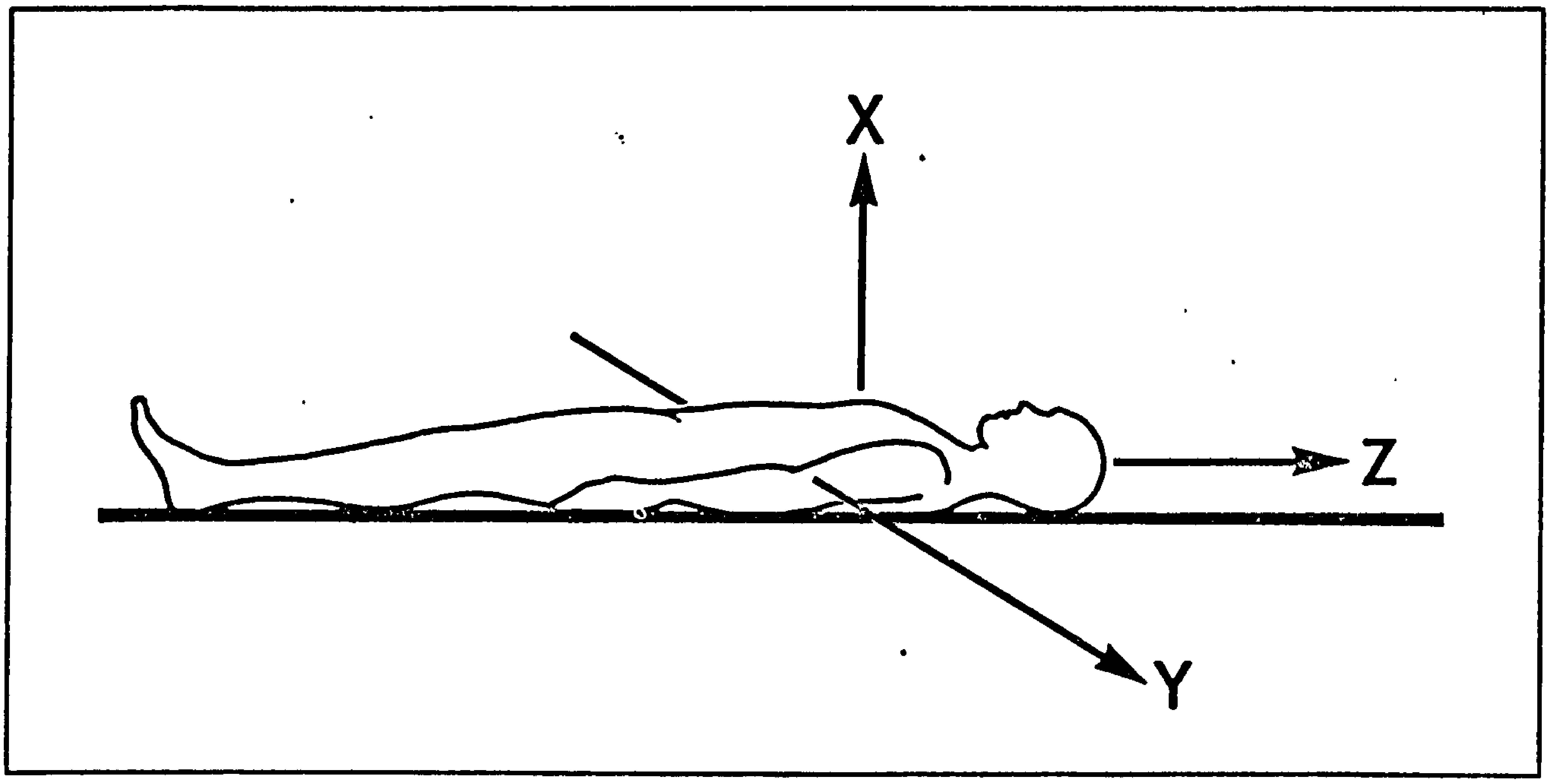


Fig. 1—Body axis convention in the supine position.

up tilt during transport caused fits and death in two patients. The only other case reported, was a woman in shock after an abortion who had prolonged fainting spells each time she was tilted head-up. No published experimental data on head-up tilt could be found, though Campbell[12] has evidence that there is no change in BP or CO when anesthetized cats in hemorrhagic shock are tilted head-up or head-down.

MATERIALS AND METHODS

Seventeen healthy adult greyhounds already used for other experiments were kept under light anesthesia. Half were breathing spontaneously and half were paralyzed with suxamethorium chloride (50 mg) and ventilated with a Palmer pump (IPPV). Portex cannulae were inserted in the right femoral artery and vein by cut-down. The arterial cannula was advanced into the abdominal aorta, and the venous cannula into the right atrium under fluoroscopic control. Aortic pressure (BP) and right atrial pressure (RAP) were measured using capacitance transducers (Elema Schönander EMT 35 and 33 respectively) and recorded with the ECG (lead II) on an Elema Schönander ink-writing recorder (Mingograph 81). Mean BP (mBP) and mean RAP (mRAP) were obtained by integration, and HR was counted from the ECG. CO was measured by the dye dilution technique.[13] 2,500 units of heparin was given intravenously.

At the start of each experiment the dog was bled via a catheter in the left femoral or left carotid artery until mBP was 40 mm Hg, and bled further over the following 15 to 60 minutes until the mBP was stable at this level. No blood was removed thereafter. Two sets of readings ten minutes apart confirmed stability of the preparation.

Of the 17 animals, six died during bleeding or stabilization, 11 were used for detailed study. In the first three, the data was incomplete and not included, although the changes were similar to those reported. Of the remaining eight dogs: five had one study only, two had both a simulated transport and a tilting study with re-stabilization: one dog breathed spontaneously during a simulated transport study and after a period of re-transfusion, was paralyzed, re-bled, and used for further simulated transport and tilting studies under IPPV.

After stabilization, six dogs were subjected to ten minutes of simulated transport. The dogs laid supine tied to a 50 kg table on small solid rubber wheels resting on a stone floor.

The table was shaken, jolted, and rocked in three axes, then lifted and dropped two to three inches by four people. Acceleration was measured during one experiment by an Ether Blaz accelerometer strapped to the dog's chest and recorded on the Mingograph 81 *(Fig. 2)*. After four minutes there was a ten-second rest to record ECG, BP and RAP and after an additional two minutes, there was a 15 to 30-second rest to measure CO. After a total of ten minutes movement was stopped and ECG, BP, RAP and CO were measured immediately and repeated after ten minutes of rest.

After stabilization six dogs were subjected to head-up tilt for ten minutes with the table making an angle of 15° to the horizontal. The BP and RAP transducers were lifted level with the estimated position of the right atrium and re-zeroed. ECG, BP and RAP were recorded continuously, and a measurement of CO was obtained at five and ten minutes. The table was then returned to the horizontal, the transducers re-zeroed, and measurements repeated.

RESULTS

Movement

There was no pattern of change in HR or RAP during the simulated transport studies. Five of the six dogs had a rise in BP (systolic, diastolic and mean) over the first one to two minutes. BP fell over a similar period following the end of the movement. A representative response is illustrated in Figure 3. The one dog which had a fall in BP had been deteriorating at rest. All six dogs had a rise in CO.

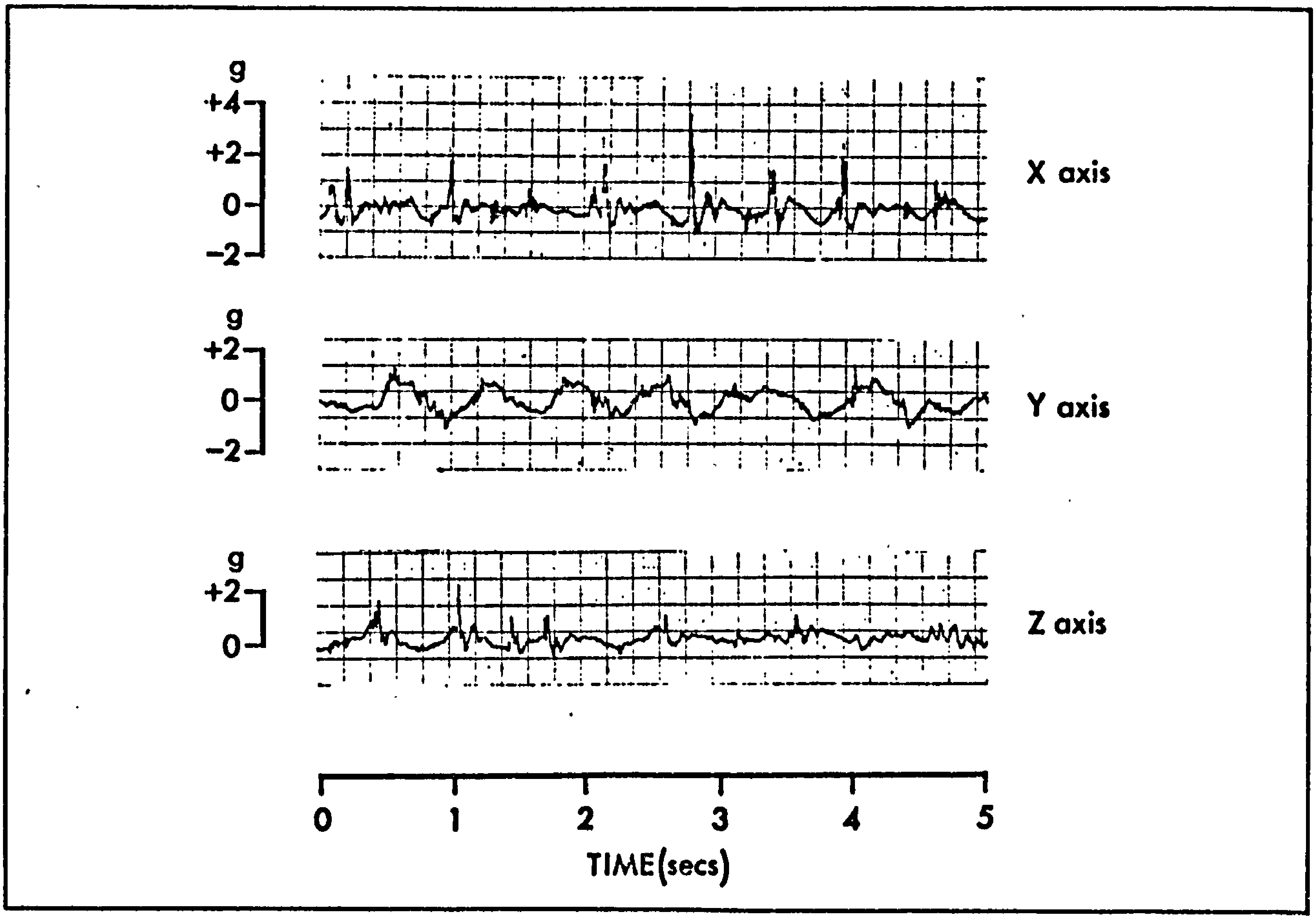
Head-Up Tilt

Head-up tilt did not significantly influence HR. Four of six dogs had a fall in BP (systolic, diastolic and mean). In one the fall in BP was immediate on tilting *(Fig. 4);* more commonly, the fall in BP was slower as in the dog which apparently died as the result of the procedure *(Fig. 5).* BP usually returned to normal within a few seconds of ending the tilt. Five had a fall in RAP; probably significant despite the doubt regarding the zero. Two had a marked fall in CO, leading to asystole in one *(Fig. 5).*

Simulated Transport

The accelerometer readings during simulated transport *(Fig. 2)* showed a main frequency of approximately 1.5 Hz with lower amplitude secondary vibrations at higher frequencies. The peak amplitudes of the 1.5 Hz vibration were 3g, 1.5g and 1.5g in the X, Y and Z axes.

Fig. 2—Accelerometer readings during simulated transport.



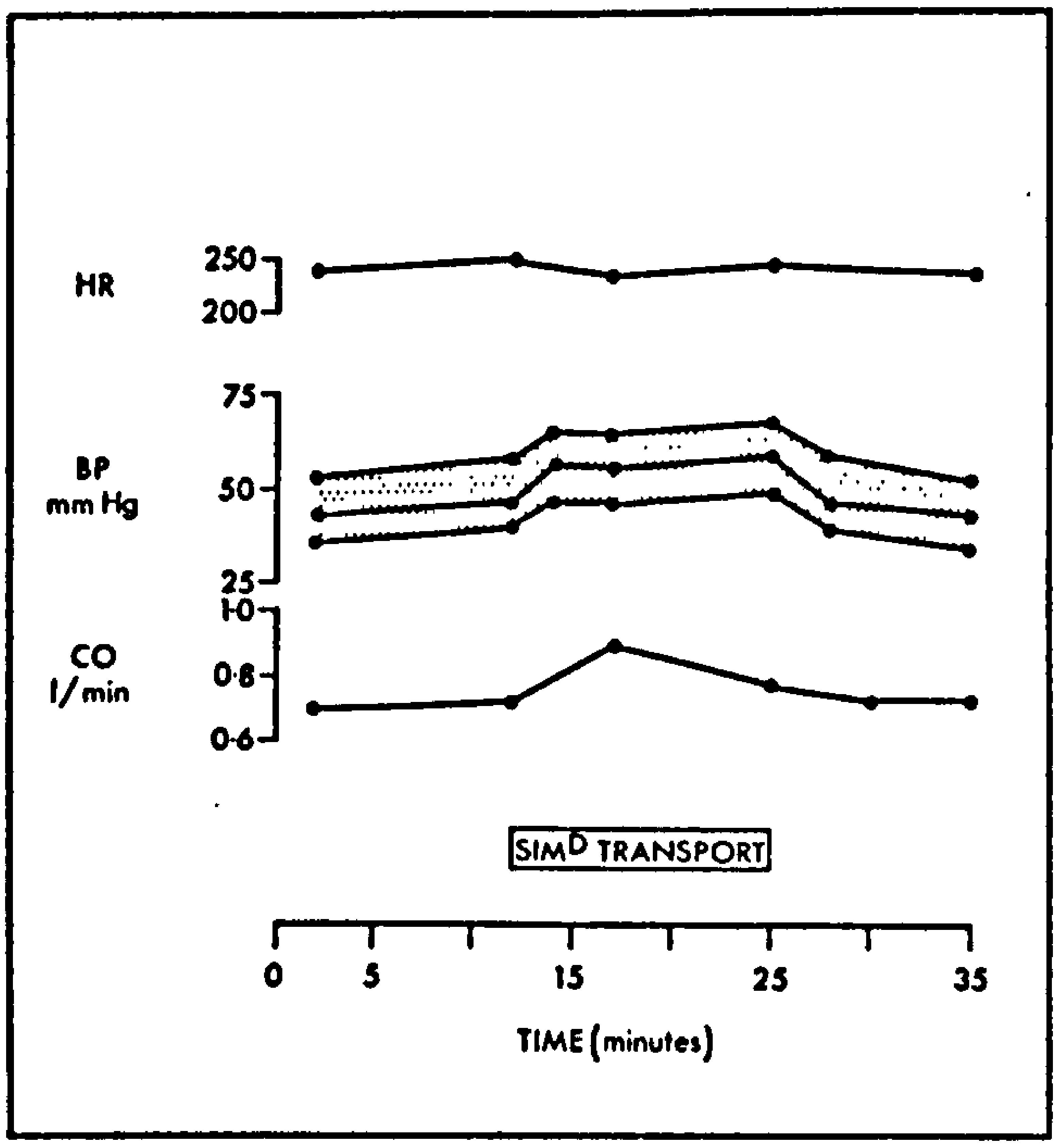


Fig. 3—A typical cardiovascular response to simulated transport.

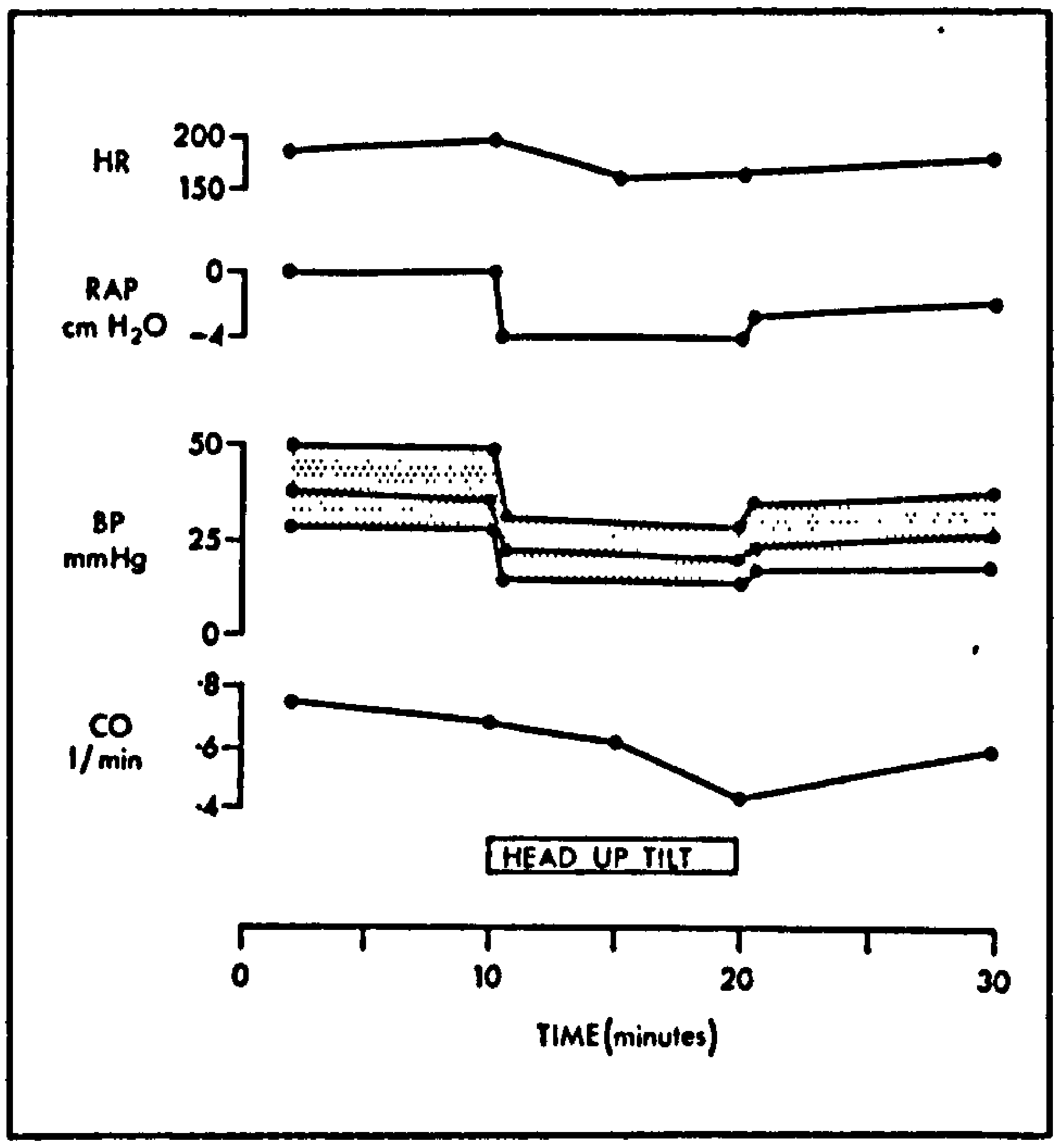


Fig. 4—Cardiovascular response to 15° head-up tilt.

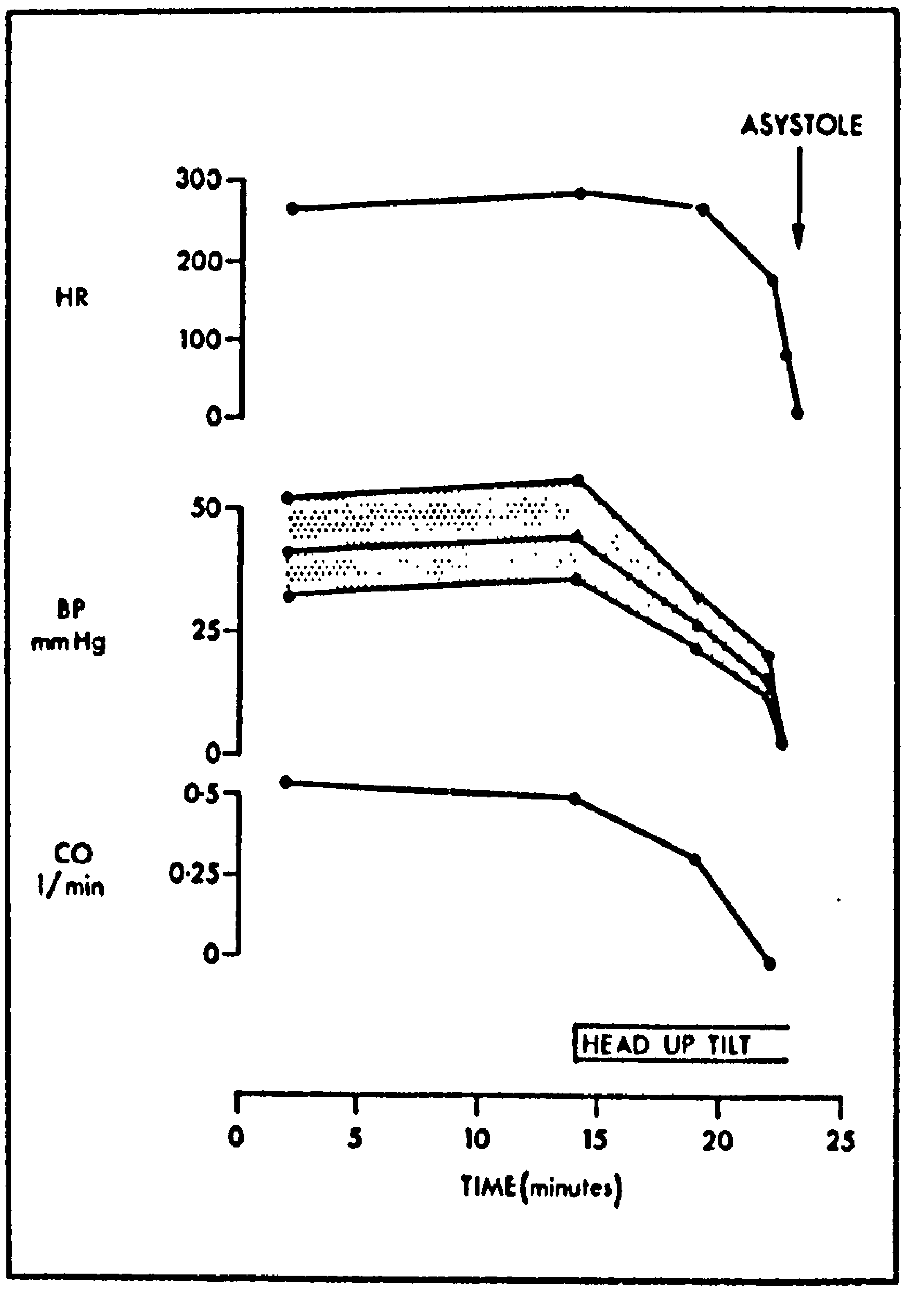
DISCUSSION

HR measurements are considered reliable, and by avoiding measurement during movement, BP and RAP measurements are also reliable, though in the tilting studies the difficulties of changing the zero, casts some doubt on the RAP measurements. In the simulated transport studies, by measuring when movement is stopped, the ECG, BP and RAP readings will reflect steady state changes and any rapid fluctuations in response to movement will be missed. The dye dilution measurement of CO has an error of ±10%[13]; some of the changes observed in this study were not much greater than this variation.

The pattern of the accelerometer readings was very similar to that reported in ambulances by Pichard and associates.[3] The main frequency of 1.5 Hz with lower amplitude secondary vibrations at higher frequencies is very similar to the ambulance readings.[3,4] The peak amplitudes of the 1.5 Hz vibration of 3g, 1.5g and 1.5g in the X, Y and Z axes respectively, compared with 1.4g, 1.2g and 0.6g in ambulances at 25-30 Kmh.[3] The vibration characteristics of the simulated transport probably approximate those of a poorly sprung ambulance at higher speed. The simulation seems much closer to an ambulance than the one axis, single frequency, constant amplitude vibration used in previous experiments.

Stability in this preparation was difficult to

Fig. 5—*Cardiovascular response prior to death during head-up tilt.*



achieve. After a period of continued bleeding to maintain mBP at 40 mm Hg, dogs normally begin to "take up" blood. This take-up point is generally regarded as the onset of irreversible shock.[14] The brief period between "no longer requiring further bleeding" and "beginning to take up blood" was used in this experiment. This period may be short and cannot be judged accurately in advance. In five dogs, BP and CO appeared to be recovering throughout the experiment, while in one BP and CO appeared to deteriorate throughout.

In the simulated transport studies the full sequence of changes was seen in BP in three of six dogs, and in CO in three. In the tilting studies the full sequence was seen in BP and CO in one dog. It may be concluded that these changes were due to the experimental procedure.

Although not strictly comparable, the changes seen during simulated transport may be contrasted with those seen in healthy dogs on a vibration table. The lack of change in HR in shocked dogs, may have been due to the fact that they already had almost maximal sympathetic activity and were unable to increase HR any further. The rise in BP was difficult to assess, although a transient fall may have been missed in this experiment; however, limited observations during movement did not support such a suggestion. It may be that the vasoconstriction of shock prevents the fall in peripheral resistance which was observed in unshocked dogs who were vibrated.[9] The rise in CO in shocked dogs was comparable to that in unshocked dogs. The changes in shocked dogs appear to be largely cardiac in origin while the peripheral effects may be masked by the shock process. In summary, the response to movement in shocked animals appears to be similar to that of healthy animals, modified by the pattern of illness. Experimental results on healthy subjects cannot be extrapolated to critically ill patients. In the present experiment; movement did not have very harmful effects on anesthetized dogs in hemorrhagic shock. This may not apply to conscious humans.

The marked fall in BP and CO on tilting in the one case leading to asystole, appears to confirm clinical impressions. The fall in RAP suggests that the mechanism may be related to diminished venous return from the lower body. These observations strongly suggest that head-up tilt should be avoided when moving shocked patients. Although not evaluated in this study, there is also serious doubt as to the value of head-down tilt. This may not only be ineffective, but also disadvantageous to respiration.

Current clinical studies have given an impression that IPPV might have some protective action against the effects of transport in critically ill patients. In the present study both the effects of tilting and to a lesser extent the effects of simulated transport appear more marked in those dogs on IPPV. The one dog subjected to simulated transport during spontaneous breathing and while on IPPV showed a very similar response under both conditions. There is no evidence to suggest that IPPV has a protective action.

CONCLUSIONS

In lightly anesthetized dogs with severe hemorrhagic shock, simulated transport tends to cause a rise in blood pressure and cardiac output while a 15° head-up tilt may cause a fall in blood pressure and cardiac output which may lead to asystole. There is no evidence that IPPV has any protective action against these effects.

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