Papers and Originals

Analysis of 150 Patients with Acute Myocardial Infarction Admitted to an Intensive Care and Study Unit

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The clinical management of patients with acute myocardial infarction is undergoing critical review from the point of view of both practical nursing and medical supervision and also the methods of treatment employed. With the development of improved resuscitative techniques (Emergency Resuscitation, 1961) and D.C. electrical treatment of cardiac arrhythmias (Lown *et al.*, 1962), interest has been directed towards the use of intensive care units with special provision for early detection and treatment of arrhythmias and cardiac arrest.

The care and research unit at Hammersmith Hospital (Shillingford and Thomas, 1964) was designed for the study of the physiological consequences of acute myocardial infarction as well as providing facilities for immediate handling of emergencies. The factors contributing to the patient's illness and the effects of treatment have been analysed by means of continuous monitoring of the electrocardiogram (Fluck *et al.*, 1967) and haemodynamic (Thomas *et al.*, 1966; Shillingford and Thomas, 1967), respiratory (Valentine *et al.*, 1966), and metabolic (Valori *et al.*, 1967) investigations.

The purpose of this paper is to present an outline of the major clinical problems encountered in the first 150 patients treated in this unit, to relate the findings to the practical use of intensive care units, and to consider some problems in the assessment of new forms of treatment.

Methods

The patients were treated in the unit previously described. It is a single-bed unit in a side room adjacent to the main male medical ward. The basic furniture is standard, but the bed has detachable ends and boards beneath the mattress to facilitate resuscitation after cardiac arrest, and is adjustable to allow rapid change in the patient's posture. Electronic recording apparatus for intravascular and intracardiac pressures, E.C.G., phonocardiography, and respiration rate is ranged along one wall. Apparatus for measurement of cardiac output by dye dilution is included. Recordings may be made direct on to paper, on continuously running magnetic tape, and displayed on oscilloscopes. A Lown cardioverter, drugs, and other equipment for resuscitation are kept permanently installed, together with sterile packs of instruments for the percutaneous insertion of arterial and venous catheters.

A closed-circuit television camera mounted above the patient is relayed to screens in the nurses' room and the laboratories, where the E.C.G. is also shown on oscilloscopes.

The unit has been in operation since 1963, and during this time methods of patient care and study have changed to some extent. At an early stage the automatic warning device on the Lown cardioverter was used to signal onset of cardiac arrhythmias, but during the last three years continuous supervision by a nurse at the bedside has been the rule. Warning

of cardiac arrest is given by the nurse pressing a switch at the head of the bed, resulting in immediate alert of the routine resuscitation team. This consists of duty medical, surgical, and anaesthetic registrars.

The average period spent by patients in the unit was five days, with subsequent transfer to the proximal end of the adjacent ward. Bedside oscilloscopes were then employed for one to several weeks.

Principles of Therapy and Current Policy

Oxygen was given routinely by means of a face-mask allowing patients to breathe approximately 40-50% oxygen. No drugs were given as prophylactic therapy without specific indications. Severe pain was treated by analgesic drugs: morphine sulphate 5-10 mg. intravenously or intramuscularly, pethidine 25-100 mg. intramuscularly, or DF118 (dihydrocodeine bitartrate) 100 mg. intramuscularly. Less severe pain was treated only if the patient was distressed.

Ventricular ectopic beats at a frequency of 5/min. or more are regarded as a prodromal sign of more serious ventricular arrhythmias and for one year have been treated routinely by an intravenous infusion of lignocaine 5% (1-2 mg./min.) by means of a constant-rate infusion pump. Patients in whom ventricular ectopics persist despite lignocaine treatment are given procainamide 50 mg. intravenously at five-minute intervals to a total of 1 g. Subsequently intramuscular injections of 500 mg. are given four- to six-hourly. Ventricular tachycardia has been treated for one year by an immediate intravenous injection of lignocaine 1-2 mg./kg. body weight while preparation for D.C. shock treatment is being made. Failure to respond to lignocaine was followed immediately by D.C. shock (25-50 w.sec. in the first instance). Lignocaine infusion is always continued after successful conversion to sinus rhythm.

Atrial arrhythmias were managed more on a basis of their haemodynamic significance to the individual patient. Patients with varying supraventricular arrhythmias without consequent fall in arterial blood pressure or heart failure assessed on clinical and radiological grounds were managed conservatively in the first instance. If deterioration in the overall clinical state of the patient followed or if the arrhythmia persisted for four hours treatment was given. Atrial fibrillation was treated with digoxin. Atrial flutter and tachycardia were treated with digoxin initially. In those cases failing to respond within a few hours D.C. shock treatment was given. Immediate D.C.

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shock was given in the first instance if the clinical state was rapidly deteriorating. Supraventricular extrasystoles were not routinely treated.

Sinus or nodal bradycardia which led to a fall in arterial pressure was treated with intravenous injections of atropine sulphate (Thomas and Woodgate, 1966) 0.3–2 mg. or isoprenaline 0.05 mg. intravenously or by intravenous infusion (1 mg./500 ml. dextrose or more dilute solution) (Lown *et al.*, 1967).

Complete heart block in most patients was treated by internal cardiac pacing by means of a unipolar electrode. Patients with first- or second-degree block or complete atrioventricular dissociation and normal ventricular rate were closely observed and not paced unless complete heart block followed. Introduction of a pacemaker catheter in anticipation of its use in the event of complete heart block was not undertaken in this series.

Cardiovascular failure in sinus rhythm was treated on the following principles. Systemic hypotension with adequate organ perfusion as assessed by normal skin temperature and colour, cerebral function, and the passage of urine was treated conservatively or by raising the foot of the bed. Pulmonary oedema was treated by diuretics with or without digoxin. Advanced cardiovascular failure without cardiac arrhythmias associated with a shock syndrome was treated with digoxin and a variety of drugs according to the factors regarded as contributing to the patient's illness. To date no routine treatment has been established and no clear indications have been adopted for the use of therapeutic regimens involving dextrose infusion or α -blocking drugs.

In addition to clinical and electrocardiographic observation, measurements of haemodynamic, respiratory, blood gas, and biochemical factors were integrated with the patient's routine management. With the aid of these the patient's clinical state was defined more precisely and the effects of treatment were assessed.

Material

The first 150 patients (124 male, 26 female) with acute myocardial infarction admitted to the unit were taken for analysis. Their ages ranged from 32 to 87 years. Patients had been accepted from all potential sources, including general practitioners, the emergency bed service, other hospitals, casualty admissions, and referral from other services within the hospital. No objective selection was made. The diagnosis of acute myocardial infarction was accepted on a basis of a typical clinical history with serial electrocardiographic S-T segment changes representing acute myocardial infarction. Raised serum aspartate aminotransferase or lactic dehydrogenase level supported the diagnosis in most cases. Patients without diagnostic acute E.C.G. changes with S-T segment elevation were accepted if serum lactic dehydrogenase became elevated. Late admissions (more than 48 hours after onset of symptoms) were accepted if there was a clear acute history and subsequently an evolving E.C.G. pattern of acute infarction. In one patient post-mortem evidence of acute infarction was accepted in lieu of acute E.C.G. or enzyme changes.

The 150 patients had 156 separate hospital admissions for acute myocardial infarction; the total number of infarctions, including reinfarction in hospital, was 159. Twenty-one patients had a documented history of one previous infarction, three had two previous infarctions, and two had three. Twenty-one patients had evidence of systemic hypertension. Nine patients, one of whom became precomatose after acute infarction, had diabetes mellitus. Fifteen patients had chronic bronchitis, three had advanced peripheral arterial disease, five were anaemic, and one presented with melaena.

Classification of Patients

Because of the multiplicity of varying factors which determine the clinical status of patients with acute myocardial

infarction, categorization of the severity of illness is difficult. In order to facilitate evaluation of clinical problems a division was made into three groups on the basis of arbitrary criteria.

Group 1 (56 infarctions)

There were patients who on retrospective analysis had an uncomplicated clinical course. Clinical evidence of cardiovascular failure was absent at all times and no specific treatment was given except for analgesia and sedation. The group includes some patients in whom arrhythmias occurred as a transient phenomenon without significant effect on the clinical situation.

Group 2 (59 infarctions)

Patients placed in this group were those remaining after selection of groups 1 and 3. They had an illness which involved cardiovascular failure, cardiac arrhythmias with resultant clinical deterioration, or superadded complications. The group was heterogeneous in the type of therapeutic problem and the range of severity of the illness was wide.

Cardiac arrhythmias which led to clinical deterioration were dominantly important in 21 patients. Eight patients had atrial fibrillation with rapid ventricular rate or supraventricular tachycardia which either resolved spontaneously or was successfully treated with digoxin. One patient became oliguric after an episode of atrial fibrillation. Blood urea rose to 360 mg./100 ml. but diuresis occurred spontaneously. One patient had alternating atrial and ventricular tachycardia which stopped after treatment with propranolol. Twelve patients had a bradycardia hypotension syndrome which resolved spontaneously or was treated with atropine or isoprenaline. None of the patients in group 2 received electrical treatment for cardiac arrhythmias.

Forty-nine patients had cardiac failure as assessed by marked radiological pulmonary oedema and physical signs of left ventricular failure (26 patients) or some evidence of pulmonary oedema with cardiac enlargement, third heart sound, and raised central venous pressure (20 patients), or persistent reduction of arterial pressure with reduced stroke volume (three patients). In two patients pulmonary oedema failed to resolve, and though they left hospital they were readmitted to die weeks or months later. Two patients developed a murmur of mitral incompetence, but this did not progress to a serious degree.

Group 3 (41 infarctions)

Patients placed in this group had a serious illness of a degree which either led to death or almost certainly would have done had not urgent treatment been given within minutes. The group includes patients in whom cardiac arrest occurred, those who had cardiac arrhythmias which led to dramatic deterioration in clinical state, and those who had extreme cardiovascular failure with a "shock" syndrome. The group is assessed in two subdivisions.

Patients Who Survived and Left Hospital.—Eleven patients were saved from death by emergency measures. Seven were resuscitated after ventricular fibrillation on one or more occasions. These episodes occurred on the first day (two), third and fourth days (same patient), eighth and ninth days (several times in one patient), 10th (two patients), and 14th days respectively (see Chart). All these patients had other acute arrhythmias which occurred within the first four days of illness, with the exception of one patient who had 11 episodes of ventricular tachycardia, some followed by ventricular fibrillation during the second week. One of the above patients on a different occasion, and two others, deteriorated abruptly with heart failure and hypotension after the onset of ventricular tachycardia. D.C. shock resulted in sinus rhythm and rapid

improvement. Three other patients survived after a period of cardiac pacing on account of complete heart block associated with Stokes-Adams attacks and cardiovascular failure. One of these was moribund on admission.

Patients Who Died.—Thirty patients (23 male, 7 female) died. Their ages ranged from 36 to 76 (mean 65). In all except four there was evidence of severe failure of the myocardium, as indicated by moderate or marked radiological pulmonary oedema in 20, an inadequate response to electrically effective pacing in four, and a persistent hypotensive syndrome with low stroke volume in two. The terminal cardiac arrhythmia was ventricular fibrillation in 12, asystole in 11, both rhythms in two, recurrent ventricular tachycardia in one, and unknown in four. In only four patients did death occur in association with an arrhythmia without evidence of very serious ventricular failure. These patients had respectively recurrent ventricular fibrillation (five successful resuscitations) on the first day, ventricular fibrillation after eight hours' successful pacing on the first day, an acute sinus bradycardia with asystole on the 15th day, and ventricular fibrillation in relation to a second infarction on the 28th day. The time of death varied widely from one hour to the 48th day after admission. Ten patients died within the first three days of illness, but over the next two weeks deaths were fairly evenly distributed (see Chart). Appraisal of the factors contributing to death within the first 17 days did not show any simple pattern. The dominant problem in 17 of the 24 patients dying within this period was severe ventricular failure not responding to conventional therapy. Eight patients had acute arrhythmias which preceded death on days 1 (two), 2, 3, 9, 13, 15, and 17 respectively.

Day on which deaths, cardiac arrests, and arrhythmias which required immediate treatment occurred. Times are given with respect to the onset of acute symptoms.

Cardiac Arrest, Resuscitation, and Pacing

In 39 patients effective cardiac contraction was lost owing to ventricular fibrillation or asystole on one or more occasions. Nine patients were successfully resuscitated and left hospital. Five others were successfully resuscitated, one patient five times, but ultimately died. All except two resuscitated patients who left hospital had ventricular fibrillation. All except one were alive at the time of writing; one died from ventricular failure some weeks after leaving hospital.

Cardiac pacing by means of a transvenous catheter introduced via an external jugular or medial cubital vein was undertaken in nine patients with complete heart block. The site of infarction was anterior in five and inferior in four. One patient with an anterior septal infarct and two patients with inferior infarcts showed marked improvement after pacing was established, and all three subsequently left hospital, one after further resuscitation from ventricular fibrillation on the 14th day. Of the remaining six patients four showed little general improvement after electrically effective pacing and died in persistent heart failure and two died from episodes of ventricular fibrillation and asystole respectively after short periods of satisfactory improvement. The three patients who survived to leave hospital

were characterized by having a comparatively inexcitable right ventricle during catheter positioning and clear improvement in their systemic circulation with the onset of pacing.

Other Complications

Three patients had a further myocardial infarction while in hospital. Deep vein thrombosis was clinically diagnosed in 10 patients. All except one patient with melaena were treated with anticoagulant drugs. None of these developed a serious pulmonary infarction. In seven other patients without clinical evidence of deep vein thrombosis a significant pulmonary infarction was indicated by clinical and radiological evidence. One patient with rapid atrial fibrillation developed an acute hemiparesis attributed to a cerebral embolus. Twenty-one patients had a respiratory infection at some time. Most of them had pulmonary oedema or were particularly immobile. One patient had a lung abscess after resuscitation which was surgically drained. Nine patients had a radiologically significant degree of pulmonary collapse, either of a lobe or a major segment; in two this was observed after resuscitation. Renal failure requiring peritoneal dialysis occurred in one patient who later died.

Discussion

The need for a complete review of practical nursing and medical supervision, together with a basic study of the factors concerned in the illness and treatment of patients with acute myocardial infarction, is increasingly recognized. While no proved universal treatment is available, onus is placed on the optimum clinical management of each individual patient. Data from intensive care units of varying complexity are accumulating, but the role of these in hospitals of widely different nursing, medical, and financial resources is not yet clear. It may therefore be of value to consider in outline the experience of the first 150 patients admitted to the intensive care unit at Hammersmith Hospital in so far as it is relevant to intensive care, supervision of patients, and the assessment of improvement in treatment.

Patients admitted to this unit have been objectively studied in order to provide basic information on the consequences of acute myocardial infarction and the effects of therapy. As a result the factors concerned in the illness of the patients have been defined with more precision than standard clinical methods allow. For the present purpose, however, only the salient clinical events are discussed.

Continuous supervision of the patients for early warning of cardiac arrhythmias is a first priority for those with acute myocardial infarction. Methods of resuscitation after cardiac arrest and D.C. shock treatment of life-threatening arrhythmias are now well established, but early warning is essential. Initial experience with an electronic alarm system dependent on the E.C.G. was not encouraging, though new skin electrodes (Fluck and Burgess, 1966) improved the reliability. The current monitoring policy (Thomas, 1967) is to display the E.C.G. continuously on oscilloscopes and to depend on nursing observations for warning of cardiac arrest. Continued attention to the development of reliable automatic warning devices is, however, required on account of the practical problem of providing nursing supervision of large numbers of patients.

One outstanding feature of the assembled data is that the majority of patients who were clearly saved from death left hospital merely as a result of early warning of an emergency and the use of the D.C. cardioverter for the treatment of ventricular fibrillation and other arrhythmias. From the point of view of general provision of intensive care facilities, it may therefore be important to recognize that a large part of potential improvement in mortality may be achieved without great expense. Facilities for pacing, with available staff trained in

the technique, resulted in three patients surviving an almost certainly lethal situation. One of these died in the ensuing months. All other patients with one exception, in whom intensive care facilities were regarded as life-saving, remain alive and generally well. Three are alive nearly four years after cardiac arrest and resuscitation.

Evaluation of benefit which is less tangible than resuscitation from a cardiac disaster is difficult and involves subjective impression. It is very probable, however, that some patients with complex cardiovascular failure states were materially improved by immediate attention from interested medical staff; whether it was life-saving is conjectural. The difficulty in assessing treatment of cardiovascular failure and more particularly the extreme shock syndrome will recur as new forms of therapy are practised. The large number of patients in group 2 and the heterogeneity of their illnesses emphasize the problem. Within this group the range of severity of the patient's illness was wide and the accuracy of a prognostic attempt based on initial clinical evaluation was worst. By definition all patients survived, but many had an illness at some stage apparently comparable with that of some patients who died. The variability in natural history appeared to depend particularly on the unpredictable course of the myocardial functional defect and later cardiac arrest.

It is of current importance to try to define the periods of time during which intensive care effort is most rewarding. With regard to possible "flying squad" ambulances (Pantridge and Geddes, 1967), it may be significant that two of the long-term survivors from ventricular fibrillation arrested when first seen in the hospital less than half an hour after onset of symptoms. The incidence and time of occurrence of later acute emergencies differ somewhat from the experience of others. Comparatively few life-threatening cardiac arrhythmias and cardiac arrests were seen in the early stages of the illness and rather more in the second and third weeks. Though the question of selection of patients is relevant to this pattern, it is apparent from the Chart that the time of emergency with respect to the onset of symptoms, as opposed to time of admission, is such that the practical implications should be considered. Half of the successful resuscitations after cardiac arrest in this series occurred later than the third day after onset of symptoms. To take account of this, intensive care units in which only 48- or 72-hour admission is possible would require an associated observation ward where some form of arrhythmia supervision is continued.

With regard to the pattern of arrhythmia emergencies, it is also worth commenting that more than two-thirds of the patients were admitted within 24 hours of the onset of symptoms. There may therefore possibly be a true difference in frequency of early life-threatening arrhythmias in these patients as compared with other series. One could speculate that this might be due to the reassuring and sedative atmosphere of a comfortable quiet room with full supervision as compared with the busy environment of an open ward.

The overall mortality of infarction, 19%, compares well with other published figures, especially as some patients with complete heart block were transferred in extremis from other hospitals. Other patients were referred within the hospital on account of particularly serious illness.

Mortality figures always require careful interpretation, since many factors other than those related to the disease and its treatment may be concerned. The most important considerations are patient-selection and criteria of diagnosis. The type of patient admitted may be determined by influences inherent in referral sources, availability of beds, and admission arrange-

ments within the hospital, even if no objective selection is made. Inclusion of patients with anginal syndromes indistinguishable from the clinical picture of frank infarction may easily be incorporated into clinical trials on arbitrary electrocardiographic T-wave criteria. Such patients have a low acute mortality and may be a major influence on overall figures. Nineteen such patients were excluded from this series.

Summary

The major clinical events occurring among the first 150 patients admitted to the intensive care and study unit at Hammersmith Hospital have been presented. Each patient was closely observed for an average period of about five days in the unit and subsequently in the proximal end of the general ward. The factors contributing to serious illness and response to treatment were studied by electrocardiographic, haemodynamic, respiratory, and biochemical investigations, but clinical events were assessed mainly with respect to general application of the principles of intensive care.

The overall mortality of infarction was 19%. Fourteen patients were successfully resuscitated from cardiac arrest on one or more occasions. Nine of these ultimately left hospital, and all except one remain well. Most of these patients were saved from death merely by early warning of cardiac arrest and immediate use of resuscitative techniques and a D.C. defibrillator. Internal pacing of the heart was life-saving in three patients. The emergencies in a significant proportion of patients treated for cardiac arrest and life-threatening arrhythmias occurred later than the third day of illness. It is suggested that some provision for early warning and resuscitation should be continued for a period longer than 48-72 hours.

A simple representation of the benefits that intensive care gives in the management of cardiovascular failure not secondary to cardiac arrhythmias is not possible. A general review of the subject and principles of therapy for routine patient management is given elsewhere (Shillingford and Thomas, 1967). Some problems in the assessment of the overall influence of intensive care on mortality and morbidity following acute myocardial infarction are discussed. Several factors, including patient selection and criteria for diagnosis, are important.

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