Middle Articles

Mobile Intensive Care in Myocardial Infarction

R. J. KERNOHAN,* M.D., F.R.C.P.I., M.R.C.P.; R. B. MCGUCKEN,† M.B.

Brit. med. J., 1968, 3, 178-180

Summary: In the first six months of its existence a mobile intensive care unit was used to admit 95 patients with definite or probable myocardial infarction to the local district hospital. Though the area served was a rural one, with a radius of about 25 miles from the hospital, the average interval between receiving a call and starting intensive care was less than 30 minutes. Five patients with ventricular fibrillation were successfully resuscitated by the mobile team outside hospital. The mobile unit has made it possible to admit many more patients with myocardial infarction to hospital than before, and we believe its cost and use of skilled staff are justified by the results. The unit reduces the delay between the onset of symptoms and initiation of intensive care and thus diminishes the risk of primary ventricular fibrillation, which is maximal soon after the onset of symptoms. Since mobile intensive care removes the risk of transport it allows concentration of cases of acute myocardial infarction in the larger hospitals.

The incidence of arrhythmic deaths is highest in the first few hours after myocardial infarction (Lown *et al.*, 1967a). In fatal coronary heart disease death occurs within one hour of the onset in 60% and within 24 hours in 85% (Yater *et al.*, 1948; Bainton and Peterson, 1963). Pantridge and Geddes (1966, 1967) have pioneered the use of a mobile intensive care unit in Belfast. The rapid initiation of intensive care in myocardial infarction is an attempt to prevent death from cardiac arrest shortly after the onset of symptoms and to prevent death during transport. Pantridge and Geddes (1967) report in a 15-month period 10 examples of successful resuscitation outside hospital with 50% long-term survival, indicating that correction of cardiac arrest outside hospital is a practical proposition. While the value of mobile intensive care in a densely populated urban area has been established, some doubt has existed regarding its value in a rural area. We therefore describe here our experience of the first 146 patients admitted by a mobile intensive care unit providing a service for a rural community of approximately 165,000 over a period of six months.

Method

An ambulance has been equipped with a direct-writing electrocardiograph, a battery-operated E.C.G. monitor, a battery-operated D.C. defibrillator, pacing catheters, and pacemaker. A wooden bench, 6 ft. (1.8 m.) long, 19 in. (48 cm.) wide, and 16 in. (40 cm.) high, was fixed obliquely across the floor of the ambulance to support the patient so that members of the team could work, if necessary, on either side of the patient and conveniently carry out resuscitative measures during transit. The patient is kept in position by means of straps attached to the bench. A strongly constructed bench for the defibrillator and E.C.G. machine was secured along one side of the ambulance. One additional doctor and three additional

ambulance drivers were appointed to supplement the staff. The telephone call from the general practitioner to the hospital is transmitted immediately to the duty doctor and ambulance driver. A nurse from the staff of the cardiac department and the doctor on ambulance duty go instantly to the ambulance. The team then proceeds as quickly as possible to the patient. The interval between receipt of the call and the departure of the ambulance from hospital has been two minutes or less. On arrival an electrocardiogram is recorded. The cardiac rhythm is carefully observed. If necessary, antiarrhythmic therapy is initiated. The patient is not moved to the ambulance until the cardiac rhythm is stable. During transportation the electrocardiograph is continuously monitored and the patient is under the same intensive care conditions as would obtain in a hospital intensive coronary care unit.

The mobile intensive care unit described here is centred in the Waveney Hospital, Ballymena, Northern Ireland. This is a district hospital providing acute medical and surgical services, including an intensive coronary care unit which was established in November 1964. The mobile intensive care service is available to a population of approximately 165,000 in a rural area. The area served by the mobile unit has a radius of approximately 25 miles (40 km.) from the Waveney Hospital. In this area there are three other provincial towns each with a general hospital. Several patients have been transported from these hospitals to the Waveney Hospital by the mobile unit. The service has facilitated the centralization of cases of acute myocardial infarction in the Waveney Hospital.

Results

During the six-month period 164 calls were received for the mobile unit. In three cases admission was not thought necessary. Ten patients were dead on arrival of the team, and in five cases resuscitation in the home was unsuccessful. The final diagnosis in the 146 patients who were admitted to hospital is shown in Table I. Seventy patients had evidence of definite acute myocardial infarction and 25 had possible acute myocardial infarction. We used the following criteria for our classification.

Definite Acute Myocardial Infarction.—Criteria include a compatible clinical history, development of diagnostic Q waves, or progressive S-T segment and T-wave changes with characteristic changes in serum aspartate aminotransferase and lactate dehydrogenase.

TABLE I.—Final Diagnosis in 146 Patients Admitted by Mobile Intensive Care Unit to Hospital with Suspicion of Acute Myocardial Infarction During a Six-month Period

	No.	%
Total admissions	146	100
Definite acute myocardial infarction	70	48
Possible acute myocardial infarction	25	17
No acute myocardial infarction:		
Arrhythmias	22	15
Cardiac failure	7	5
Other diagnoses	22	15

* Consultant Physician, Waveney Hospital, Ballymena, Northern Ireland.

† Senior House Officer, Waveney Hospital, Ballymena, Northern Ireland.

Possible Acute Myocardial Infarction.—Prolonged chest pain suggestive of myocardial infarction associated with S-T segment and T-wave changes which reverted to a normal pattern, and normal or non-diagnostic changes in blood enzymes.

No Acute Myocardial Infarction.—This category includes patients whose symptoms were due to arrhythmia, cardiac failure, or disease of other systems.

Reduction in the delay between onset of symptoms and admission to hospital results in the admission of a considerable number of patients who do not have acute myocardial infarction (Lown *et al.*, 1967b, Oliver *et al.*, 1967).

The distance 95 cases of definite and possible acute myocardial infarction were transported was less than 5 miles (8 km.) in 33 cases, between 5 and 10 miles (8 and 16 km.) in 27 cases, and more than 10 miles (16 km.) in 35 cases. Thus 37% of the patients were transported a distance greater than 10 miles. No death occurred during transportation.

Ninety-four per cent. of patients with definite and possible myocardial infarction who lived within 10 miles from the hospital were reached within 30 minutes of receipt of the call, and 96% of those who lived more than 10 miles from the hospital were reached within 45 minutes. The overall average interval between receipt of the call and initiation of intensive care was less than 30 minutes.

The rationale of providing mobile intensive care is to reduce to a minimum the interval between onset of symptoms and the initiation of intensive care. The interval between the onset of symptoms and initiation of intensive care in our cases is shown in Table II. Though one-third of our patients lived more than 10 miles from the hospital, 43% came under intensive care within two hours of the onset of symptoms and 68% within four hours.

TABLE II.—Comparison of Intervals Between Onset of Symptoms and Initiation of Intensive Care in Acute Myocardial Infarction Before and After Establishment of Mobile Intensive Care

	Before Mobile Intensive Care (% of Cases)	After Establishment of Mobile Intensive Care (% of Cases)
1 hour or less ..	—	14
2 hours or less ..	—	43
3 hours or less ..	18	53
4 hours or less ..	—	68
5 hours or less ..	—	71
6 hours or less ..	42	79

In five cases attempted resuscitation in the home was unsuccessful. One patient, aged 75, had acute left ventricular failure when his doctor arrived. Cardiac arrest occurred 15 minutes before arrival of the mobile team. E.C.G. revealed asystole, which failed to respond to transthoracic pacing and intracardiac isoprenaline. This patient appears to have sustained very severe myocardial injury. A second patient, aged 80, had cardiac arrest before arrival of the mobile unit. On arrival her pupils were dilated and fixed. In this case further resuscitation was not justified. A third patient, aged 68, had been unconscious for 15 minutes before arrival of the team. E.C.G. revealed ventricular fibrillation, which failed to revert by countershock and intravenous lignocaine. Failure in this case may have been due to delay between the onset of cardiac arrest and initiation of definitive therapy. A fourth patient, aged 70, developed cardiac arrest before arrival of the mobile team. His doctor had sustained circulation by external cardiac massage and mouth-to-mouth breathing. E.C.G. revealed ventricular fibrillation. Countershock was unsuccessful. Idioventricular rhythm developed. Artificial pacing caused a satisfactory electrical response but no effective circulation. The fifth patient, aged 60, collapsed before arrival of the team. E.C.G. revealed idioventricular rhythm followed by ventricular fibrillation. Countershock resulted in asystole, which failed to respond to artificial pacing. Delay in initiating definitive therapy may account for failure.

Five patients with ventricular fibrillation were successfully resuscitated by the mobile team outside hospital. Ventricular fibrillation developed within two hours of the onset in three patients and within four hours in all these patients. Three of these patients survived to leave hospital.

Reports of Patients Resuscitated Outside Hospital

Case 1.—A woman aged 88 collapsed after an accident in a car which she was driving. The mobile unit arrived at the scene of the accident within five minutes. A police officer had carried out external cardiac massage until arrival of the ambulance. E.C.G. revealed ventricular fibrillation. Defibrillation was achieved immediately. Recovery from myocardial infarction was uneventful, and at the time of discharge from hospital she was well.

Case 2.—A 60-year-old man had ventricular tachycardia when the mobile unit arrived at his home two hours after the onset of chest pain. While the E.C.G. was being recorded he developed ventricular fibrillation. Defibrillation was achieved. His condition was satisfactory on arrival in hospital. He made an uneventful recovery from myocardial infarction and at the time of writing he was well.

Case 3.—The mobile team arrived at the home of a 72-year-old woman three hours 25 minutes after the onset of chest pain. As she was being moved from her house to the ambulance ventricular fibrillation occurred. Defibrillation was effected. She died from congestive heart failure 24 days after admission to hospital.

Case 4.—An 80-year-old woman developed cardiac arrest before arrival of the mobile unit. Circulation had been maintained by the family doctor. Ventricular fibrillation recurred just after the team arrived, four hours after the onset. Defibrillation was achieved. After arrival in hospital she developed complete heart block. Pacing was achieved by transventricular pacing stylet, but the response was unsatisfactory. She died one hour after admission.

Case 5.—A 66-year-old man collapsed in a garage. The mobile unit was summoned, arriving within half an hour. During transportation in the ambulance he developed three episodes of ventricular fibrillation. Defibrillation was achieved on each occasion. After the third attack of ventricular fibrillation he developed asystole. Pacing by direct transventricular pacing stylet was initiated in the ambulance. After admission he had a further 22 episodes of ventricular fibrillation despite intensive antiarrhythmic therapy. Each episode was immediately terminated by defibrillation. He recovered from acute myocardial infarction, and at the time of writing was alive and well.

Cost

The capital cost involved in converting an ambulance and in providing equipment was £1,579. The running costs of the ambulance and the remuneration of the extra staff employed to provide the service for six months were £3,111. The cost per ambulance call was therefore £19. The personnel operating this scheme perform other duties in the hospital, so that the figures quoted are higher than the net cost of the service.

During the six-month period the total number of cases of definite acute myocardial infarction admitted to the coronary care unit was 96. Thus more than 70% of cases of myocardial infarction were admitted by the mobile unit. In the corresponding six months of the previous year, when mobile intensive care was not available, the number of cases of acute myocardial infarction admitted to the coronary care unit was 53. The volume of work in the coronary care unit has therefore nearly doubled since introduction of the mobile intensive care service. This increase has resulted from admission of patients by the mobile unit from a much larger area. It is now possible to treat patients with acute myocardial infarction in one central hospital in the area.

Discussion

Because the danger of ventricular fibrillation is greatest in the first few hours after the onset of acute myocardial infarction,

tion (Pantridge and Geddes, 1967) it is essential that patients should be under intensive coronary care as soon as possible. Lown *et al.* (1967b) are of the opinion that monitoring should begin, if possible, from the moment the patient is transported. We believe that monitoring should begin in the patient's home or other location where myocardial infarction develops. Provision of mobile intensive care affords intensive care conditions with the least possible delay. This requires an ambulance supplied with monitoring equipment and staffed with personnel trained in the methods of coronary intensive care.

Before the provision of a mobile intensive care unit only 18% of cases of acute myocardial infarction were admitted to the intensive coronary care ward within three hours, and only 42% within six hours. In a series reported at Hammersmith Hospital only 42% were admitted within six hours (Fluck *et al.*, 1967), and only 61% were admitted to the Peter Bent Brigham Hospital within 12 hours of the onset of symptoms (Lown *et al.*, 1967a). In contrast, with the provision of a mobile intensive care unit 43% of our patients were under intensive care conditions within two hours of the onset of symptoms, 53% within three hours, and 68% within four hours.

A mobile intensive care service minimizes the risk of death from cardiac arrest during transportation. Nixon (1967) reported his experience in London, where of 100 coronary deaths 47% occurred before the ambulance reached them and 13% occurred in the ambulance. In our series 10 patients were dead before the ambulance arrived and five could not be resuscitated in the home by the mobile team. No death occurred during transportation. One patient developed ventricular fibrillation in the ambulance. He was successfully resuscitated by the ambulance team and survived to leave hospital.

Lown *et al.* (1967a) stressed the importance of control of arrhythmias in the prevention of sudden and unexpected death from primary ventricular fibrillation in acute myocardial infarction. The admission to intensive care conditions by a mobile intensive care unit facilitates monitoring, administration of antiarrhythmic drugs, and treatment of life-threatening arrhythmias before and during transportation in the early hours after the onset when the patient is at maximal risk. Mobile intensive coronary care should therefore prevent a considerable number of the deaths due to primary ventricular fibrillation in the first few hours after acute myocardial infarction. Five of our patients who developed ventricular fibrillation were resuscitated outside hospital, with three long-term survivals.

One of the factors which may cause delay in admitting cases of acute myocardial infarction is the interval that may elapse

after the onset of symptoms before the patient summons his doctor. Since establishing a mobile intensive care service it has been our experience that both doctors and the public are much more conscious of the importance of immediate medical aid.

The relevance of mobile intensive care has been questioned. Oliver *et al.* (1967) consider that this type of service is expensive in staff and involves an uneconomic use of special skills. We do not understand this view. Since the majority of deaths due to coronary thrombosis occur outside hospital it is difficult to believe that intensive coronary care should be limited to the hospital. The only extra staff required for the service which we describe has been one doctor and three ambulance drivers, and these are not employed full time on mobile intensive care duties. The cost was £19 per ambulance call. We consider that the reduction in the mortality of acute myocardial infarction which can be achieved by the establishment of mobile intensive coronary care justifies the expenditure and does not involve uneconomic use of skilled staff.

Our experience has been in a rural area with a population of approximately 165,000. One-third of our patients were transported more than 10 miles (16 km.), and several patients came from a distance of 30 miles (48 km.). In an urban area a mobile intensive care service operating from a large teaching hospital should be less expensive. Since a mobile intensive care service, such as described here, removes the risk of transport, it is possible to concentrate cases of acute myocardial infarction in larger hospitals. This should prevent the proliferation of inadequately staffed and ineffective intensive care units in small hospitals.

We are grateful to the nursing and medical staff of the cardiac department of the Waveney Hospital for their enthusiastic co-operation. Grants were received from the Northern Ireland Hospitals Authority and the Mid-Antrim Hospital Management Committee.

REFERENCES

- Bainton, C. R., and Peterson, D. R. (1963). *New Engl. J. Med.*, **268**, 569.
 Fluck, D. C., *et al.* (1967). *Brit. Heart J.*, **29**, 170.
 Lown, B., Fakhro, A. M., Hood, W. B., and Thorn, G. W. (1967a). *J. Amer. med. Ass.*, **199**, 188.
 Lown, B., Vassaux, C., Hood, W. B., Fakhro, A. M., Kaplinsky, E., and Roberge, G. (1967b). *Amer. J. Cardiol.*, **20**, 494.
 Nixon, P. (1967). *Quart. J. Med.*, **36**, 600.
 Oliver, M. F., Julian, D. G., and Donald, K. W. (1967). *Amer. J. Cardiol.*, **20**, 465.
 Pantridge, J. F., and Geddes, J. S. (1966). *Lancet*, **1**, 807.
 Pantridge, J. F., and Geddes, J. S. (1967). *Lancet*, **2**, 271.
 Yater, W. M., Traub, A. H., Brown, W. G., Fitzgerald, R. P., Geisler, M. A., and Wilcox, B. B. (1948). *Amer. Heart J.*, **36**, 334.

MEDICINE AND THE COMPUTER

IV—Assisting Radiotherapy Planning*

[FROM A SPECIAL CORRESPONDENT]

The aim of radiotherapy in malignant disease is to deliver a lethal dose of radiation to the tumour while leaving the surrounding healthy tissue unharmed. To achieve this a unique scheme has to be planned for the treatment of each patient, and this takes time and skill. Any treatment plan must then be checked by laborious and repetitive calculations. Theoretically this process would seem ideally suited to the computer, and for the last year the radiotherapy department at the Queen Elizabeth Hospital, Birmingham, has been using this to help with treatment planning. In practice they have found that not only can the computer remove the tedium from the planning pro-

cess, but it can also do extra calculations for which the human planner has insufficient time and so lead to better treatment.

In external radiotherapy the problem of delivering a high tumour but low tissue dose is solved by using a succession of sub-total doses, or "fields," each of which enters the body from a different direction. These fields may either be applied from two, three, or four fixed positions (fixed field therapy), or by rotating the field in a circular arc around the patient (rotation therapy), so that, in effect, an infinite number of fields is applied in succession. In practice, however, for the purposes of calculation in rotation therapy the field is regarded as occupying 36 fixed positions around the patient.

Basically the treatment plan for both kinds of therapy is derived in the same way. First of all the planner has to choose the most likely set of treatment indices to produce a satisfac-

* Part I, "Managing a County Health Service" was printed in the issue of 29 June (p. 823). Part II, "Running a Mental Health Service," was printed in the issue of 6 July (p. 51). Part III, "Record Linkage," appeared last week (p. 116).