INTENSIVE CARE OF ACUTE MYOCARDIAL INFARCTION IN A CORONARY CARE UNIT

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INTRODUCTION

From the time Day reported the initial experience of the first coronary care unit in 1962 and 1963,[1-2] till 1968, 350 hospitals throughout the U.S.A. had established coronary care units for the specialised care of acute myocardial infarction patients.[3] Based on the result of a unit, and applying the projection of appropriate death rates, Fox calculated that the comparative mortality rates of patients admitted into the coronary care unit and those receiving regular care were 19.9% against 31.1%.[3] It can now be accepted that deaths in acute myocardial infarction from primary electrical failure and to some extent myocardial failure can be reduced if patients are admitted early into an area providing well organised intensive care with monitoring and alarm system.[4-10] Furthermore, there is sufficient evidence to show that prophylactic and aggressive treatment of certain arrhythmias can contribute to the lowering of hospital mortality.[11]

BACKGROUND INFORMATION

In April 1967 a coronary care unit* of 4 beds was initiated with public donations within the Department of Clinical Medicine of the Outram Road General Hospital, Singapore. Based on the approximate admission figure of 150 acute myocardial infarction patients into the unit in 1966, it was calculated that 4 beds should be more than adequate to provide intensive care for such patients in the first few critical days of the illness and other cases of arrhythmia not due to acute myocardial infarction. To estimate the bed size of a unit, the formula suggested in a joint publication of the Heart Disease and Stroke Control Program of the National Centre for Chronic Disease Control, the American College of Cardiology; and the American Heart Association,[3] is worth noting, viz.

$$\text{Number of beds} = \frac{\text{Number of MIs per year} \times \text{days in Unit}}{365}$$

DESIGN AND PHYSICAL REQUIREMENTS OF A CORONARY CARE UNIT

The various designs adopted[12] are semi-circular, circular, hexagonal and octagonal with individual beds in single cubicles but observable from a central nursing station. The atmosphere should be attractive and as non-institutional as possible. Small units of 2 to 4 beds like the one in the Department of Clinical Medicine may be planned in such a way that the beds are visible from an adjacent room or corridor with audiovisual alarms strategically sited, and where reasonable privacy is possible. Coronary care beds in open general wards are generally unsatisfactory as they lack privacy so essential for psychological well-being. There is nothing more frightening and dangerous for a patient with myocardial infarction than to witness his neighbour being resuscitated during cardiac arrest! In fact there is reason to believe that fear can induce ventricular fibrillation in such a patient.

The physical requirements may be summarised as follows:—

1. Single bed cubicles for privacy are essential; the walls between cubicles should be sound proof. Adequate floor space is important for rapid mobility of equipment and staff, and minimum dimensions of 12 feet × 15 feet are recommended for each cubicle.
2. The patients should be visible from the Central Nursing Station.

* Referred to by the abbreviations "C.C.U." in the rest of the communication.

3. The station should be fairly close to all the cubicles to enable quick access.
4. Minimum equipments include:—
   (a) Monitors with oscilloscopes either at the bedside or at the Central Station or at both places with means for E.C.G. recording at selected intervals
   (b) Audiovisual alarm for preset rates with minimum of false alarms
   (c) Synchronised D-C defibrillators
   (d) Pacemakers
   (e) Pressure recording devices
   (f) And the other usual resuscitative equipments
5. Air-conditioning is useful in the tropics both for the sake of the patients and electronic equipment. There should be ample power plugs and piped oxygen supply.
6. The Coronary Care Unit should ideally be situated near the admission room or emergency service unit.
7. It may be an advantage to site it adjacent to the general intensive care unit, but should not be part of it, for the needs of the two groups of patients are quite dissimilar.

ORGANISATION AND ADMINISTRATION

The C.C.U. in the Department of Clinical Medicine (or Medical Unit II) consists of 2 beds situated in a room adjacent to a general medical ward and opposite the renal dialysis room, and 2 other beds in the general ward next to the Sister's writing table. However as from 1st January 1970, the two beds in the general ward will be transferred into the "renal room" when the renal care unit is moved to another area.

4 monitors are available, all mounted on individual rapidly mobile trolleys. Each consists of a 3-inch oscilloscope, a ratemeter, E.C.G. direct writing recorder, and audiovisual alarm. These monitors are wired to a central audiovisual alarm along the ward corridor and to another central audiovisual alarm with slave ratemeters in the dialysis room. One synchronised D-C defibrillator is placed in the C.C. room and another in the open ward. Other equipment include two Bird respirators, a fixed rate external/internal pacemaker, a demand pacemaker, saline manometers for measuring central venous pressure and other resuscitative equipment.

The nursing care is provided jointly by the general ward nurses and the cardio-renal nurses, the latter mainly concerned with the specialised aspects. The nurses have so far not been allowed to defibrillate patients. The policy will be reviewed in the light of further experience.

The Unit is an integral part of the Department of Clinical Medicine. A cardiac physician is in full charge of the Unit assisted by a postgraduate fellow who spends most of his time in the C.C.U. carrying out routine procedures and management, and at the same time carrying out research into various aspects of myocardial infarction. Such a full-time doctor personnel is essential for the smooth running and success of the Unit.

All the medical personnel are trained in methods of resuscitation the moment they join the department, and are kept informed about the progress of the C.C.U. and current work in coronary care in other centres. At any time there is at least one resident within the Unit who can be contacted for emergencies within 1-2 minutes. In hospitals with larger units like the one in the Edinburgh Royal Infirmary there is always a Registrar on tap who has been adequately trained for emergency cardiac resuscitation.[13]

CRITERIA FOR ADMISSION

The E.C.G. criteria which the Unit has adopted for the diagnosis of acute myocardial infarction are:—

1. The classical pattern of transmural infarction.
2. Deeply inverted T waves of 5 mm. or more.
3. Acute ST segment — elevation or depression.
4. Bundle Branch Block.

Evidence of myocardial necrosis as evidenced by raised serum glutamic oxaloacetic transaminase and or raised serum lactic dehydrogenase is mandatory.

Based on these criteria 117 out of 144 patients admitted into the C.C.U. between April 1967-April 1968 were proven to have acute myocardial infarction. In addition, sixty four other patients were admitted into the general medical wards of the department but were not monitored because of any one of the following reasons:—

1. Over age of 65 and not complicated by arrhythmias.

Fig. 1. Showing 2 coronary care beds in a partitioned room.

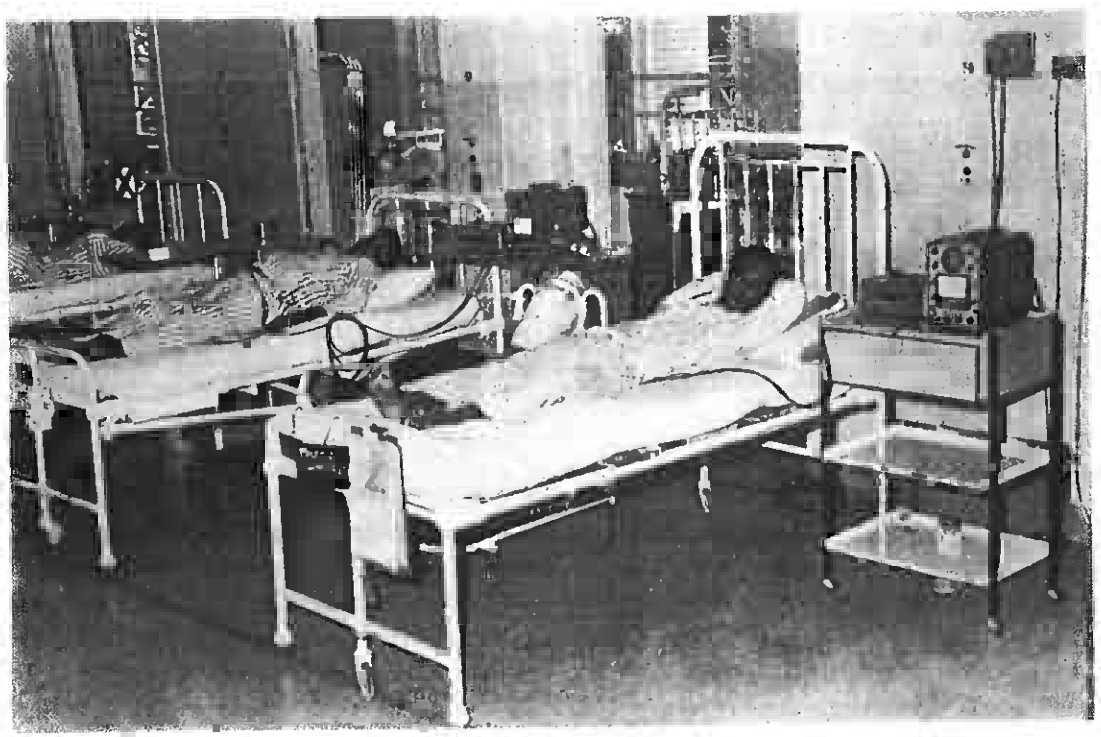

Fig. 2. Showing 2 coronary care beds in the open ward.

2. Onset of infarction occurred 48 hours or more before diagnosis.
3. Moribund when admitted into the medical wards, and there was inadequate time even to confirm the clinical diagnosis.
4. Diagnosis only at autopsy.

ADMISSION POLICY

The C.C.U. admits patients mainly from the Emergency Unit of the General Hospital and to a lesser extent directly from government outdoor clinics and general practitioners. There is often considerable delay from the time of onset of A.M.I. to monitoring in the C.C.U. In a significant proportion the patients are to blame. Failure to diagnose the condition early, lack of domiciliary consultant service, and delays at the Government outdoor dispensaries and the Emergency Unit are additional factors.

TABLE I

ONSET TO MONITORING TIME
APRIL 1967 - APRIL 1968

0—4 Hr.	4—12 Hr.	12—24 Hr.	24 Hr.
20 (17.1%)	39 (33.4%)	24 (20.5%)	34 (29%)
APRIL 1968 - DECEMBER 1968			
37 (44.6%)	26 (31.4%)	10 (12%)	10 (12%)

In the series of 117 patients monitored between April 1967 and April 1968 only 17.1% of the patients were admitted within 4 hours and 50.5% within 12 hours of onset of symptoms. Measures are continuously being taken to expedite admission direct into the unit. Between April 1968 and December 1968 the figures have improved: 44.6% of patients were admitted in the first 4 hours, and 76% in the first twelve hours and the remaining after the first twelve hours. Early monitoring is vital as the incidence of primary ventricular fibrillation falls with time.

CLASSIFICATION OF SEVERITY

For simplicity, cases are graded into:—

Grade 1 —representing the uncomplicated cases

Grade 2 —representing those with failure and perhaps slight fall in blood pressure and

Grade 3 —representing those with cardiogenic shock (The criteria accepted for this diagnosis are signs of peripheral circulatory failure associated with clouding of sensorium and cardiac failure)

ROUTINE PROCEDURE AND MANAGEMENT

Routine management in the C.C.U. consists of explanation and reassurance, routine use of tranquillisers or sedatives, and oxygen via intranasal catheter or face-mask. A strip of E.C.G. is taken hourly. Monitoring time varies from 72 hours or more depending on the nature of the case. A slow dextrose drip is routinely inserted to facilitate intravenous administration of drugs in times of emergency. The central venous pressure is recorded with a polyethylene catheter and saline manometer in cases with shock receiving I.V. therapy. An oral diuretic alone is sometimes used for mild left veintricular failure. For more severe cases digitalisation is resorted to. Ventricular ectopics of multi-focal origin, of the R-on-T type and those occurring more often than 1 in 10 beats were treated with oral antazoline during the first 12 months of our experience. Subsequently I.V. Lignocaine has been used routinely. A bolus of 50 mgm. to 100 mgm. is given intravenously for premature ventricular contractions. If they are not suppressed, repeated doses are given every 15 minutes until they disappear, following which a continuous drip of 500 to 750 mgm. per 12 hours is given, with intermittent bolus if necessary. I.V. or I.M. atropine is given for sinus bradycardia and slow nodal rhythm. 1st degree block is left alone, but watched closely. 2nd and 3rd degree blocks were treated with I.V. isoprenalin infusion. Steroids were used during the first few months of our experience but were not found to be helpful. Until September 1968 the Unit had not paced any case of heart block largely because of organisational problems. Since September 1968, the policy has been to pace all case of complete heart block. Cases with cardiogenic shock are treated with continuous oxygen, posturing, correction of any serious arrhythmias, I.V. isoprenaline, I.V. hydrocortisone at times, digitalisation and I.V. sodium bicarbonate whenever metabolic acidosis is detected.

RESULTS (APRIL 1967 - APRIL 1968)

Age, Sex, Ethnic Distribution of Patient Population (117)

The mean age for the whole series was 53.7 years for males and 58.9 for females. The maximum incidence fell in the age group between 50 to 59. There seemed to be no significant difference in age incidence among the major ethnic groups.

Relationship Between Severity and Mortality

TABLE II

SEVERITY AND MORTALITY

Grade	No. of Patients	%	DEATHS		Mortality Rate %
			No.	%	
1	66	56.4	1	3.8	1.5
2	34	29.1	14	53.8	41.2
3	17	14.5	11	42.4	64.7
TOTAL	117	100	26	100	22.2

There was only 1 death out of the 66 patients in the group with grade 1 severity, 14 deaths out of 34 in the group with grade 2 severity, and 11 deaths out of 17 in the group with grade 3 severity. The total number of 26 deaths represents a mortality of 22.2%.

The only death in the grade 1 group occurred within the first twelve hours from ventricular fibrillation. The deaths in the grade 2 group were spread out, representing largely those patients with myocardial failure with or without complicating arrhythmias. All the deaths in the cases with cardiogenic shock took place within the first 72 hours.

Modes of Death (Table III)

Broadly, deaths have been divided into those due primarily to pump failure and those due primarily to electrical failure. The term "pump" failure describes failure of the pumping action of the heart without preceding arrhythmias. It often develops quite suddenly without changes in the electrocardiogram. There was no patient in the grade 1 group who succumbed to sudden pump failure. Whilst it would appear contradictory to blame electrical failure as the mode of death in patients with cardiogenic shock, it was felt that in 4 instances arrhythmias were initially responsible for precipitating the shock.

TABLE III

MODES OF DEATH IN THE 26 PATIENTS

Mode of Death	Grade 1	Grade 2	Grade 3
A. Power ("Pump") Failure (12)			
1. Ventricular Standstill	Nil	4	7
2. Ventricular Fibrillation	Nil	Nil	Nil
3. Undetermined	Nil	1	Nil
B. Electrical Failure (14)			
1. Ventricular Standstill	Nil	5	3
2. Ventricular Fibrillation	1	2	1
3. Undetermined	Nil	2	Nil
TOTAL	1	14	11

Relationship Between Severity, Serious Arrhythmias and Mortality (Table IV)

The overall incidence of arrhythmias (excepting sinus tachycardia, sinus bradycardia alone, and prolonged P-R interval) is 63.2%. The percentage is obviously proportional to how frequent the electrocardiogram is recorded. Supraventricular tachycardia developed in 8 instances with 1 death. Atrial fibrillation occured in 11 instances, all were transient. There were 2 hospital deaths in this group. Nodal rhythm with sino-atrial block occurred in 14 instances, all in desperately ill patients. 2 were saved from a moribund state and subsequently discharged from hospital. Ventricular tachycardia developed in 13 instances, 8 terminating fatally, the majority of the fatal cases were in the grade 3 group. Acute right bundle branch block occurred in 15 instances with 10 deaths. There were 14 instances of 2nd degree and 3rd degree heart block with 4 deaths.

TABLE IV

RELATIONSHIP BETWEEN SEVERITY, SERIOUS ARRHYTHMIAS AND MORTALITY

Arrhythmia	Grade 1 (66 Patients)			Grade 2 (34 Patients)			Grade 3 (17 Patients)			All Grades (117 Patients)		
	No.	%	Deaths	No.	%	Deaths	No.	%	Deaths	No.	%	Deaths
Atrial:												
Tachycardia	1	1.5	0	0	0	0	1	5.9	1	2	1.7	1
Fibrillation	2	3.0	0	5	14.7	1	4	23.5	1	11	9.4	2
Flutter	0	0	0	1	2.9	0	0	0	0	1	0.9	0
Nodal Rhythm associated with Sino-Atrial Block	0	0	0	7	20.6	7	7	41.2	5	14	12.0	12
Supraventricular Tachycardia	1	1.5	0	1	2.9	0	4	23.5	0	6	5.1	0
Ventricular:												
Ectopics 1:10	11	16.7	0	20	58.9	11	7	41.2	3	38	32.4	14
R-on-T Ectopics	0	0	0	1	2.9	1	1	5.9	1	2	1.7	2
Tachycardia	1	1.5	0	3	8.8	1	9	52.9	7	13	11.2	8
Fibrillation	1	1.5	1	3	8.8	2	2	11.8	2	5	4.2	4
A-V Block:												
2°	5	7.6	0	2	5.9	1	1	5.9	1	8	6.8	2
3°	4	6.1	1	4	11.8	4	4	23.5	3	12	10.3	8
Bundle Branch Block:												
Right	2	3.0	1	8	23.5	7	5	29.4	2	15	12.9	10
Left	0	0	0	1	2.9	0	1	5.9	1	2	1.7	1

TABLE V

A-V HEART BLOCK (2° AND 3°)

Grade of Severity	Total No. of Patients	Deaths
1	8	0
2	4	3
3	2	1
TOTAL	$14 < \begin{matrix} 2°=7 \\ 3°=7 \end{matrix}$	$4 < \begin{matrix} 2°=1 \\ 3°=3 \end{matrix}$

In the grade 1 group there were 8 patients with 2nd or 3rd degree block, all survived. Among the 6 patients in the grade 2 and grade 3 groups, death occurred in 4, one with 2nd degree and three with 3rd degree block. Patients who had transient atrioventricular block as an agonal rhythm were not included. They were usually patients who had been kept alive temporarily with resuscitation following cardiac arrest.

19 patients terminated in ventricular standstill. This is the commonest arrhythmia in those with cardiogenic shock. The commonest premonitory arrhythmia is simple distal displacement of pacemaker, occurring mostly in those with "pump" failure.

Primary ventricular fibrillation occurred in 5 patients. 3 in the C.C.U. and 2 in the general wards. All had preceding arrhythmias. Only one patient was successfully resuscitated and discharged from hospital; he remained well 24 months after the episode. 2 other patients were successfully defibrillated but died a few hours later. Between April 1968 and December 1968 3 other cases of primary ventricular fibrillation were successfully revived by D-C countershock and discharged well.

DISCUSSION

It would appear that a well run and adequately staffed C.C.U. can lower the hospital mortality of acute myocardial infarction. Results vary from centre to centre. No strictly controlled series are available as mortality rates depend on a large number of factors, often beyond the control of hospitals. Hence C.C. Units which receive patients early tend to get sicker patients with a higher percentage of primary ventricular fibrillation and cardiogenic shock. The overall mortality of 22.2% for the first twelve months is superficially not different from the rates in other units, yet it was obvious that in the first 12 months 1 patient was revived from "death" and another 2 from a moribund state, and there were others with serious arrhythmias and cardiac failure who might have died had they not been detected and treated early in the unit. Routine tranvenous pacing of patients with second and third degree heart block would probably have saved 3 out of the 4 patients who died. Our experience since September 1968 when pacing was introduced would support this view.

The relatively low incidence of primary ventricular fibrillation in the first 12 months' series (4%) is due to two factors: (1) the delayed admission beyond 6 hours of 70-80% of patients, (2) the prophylactic treatment of premonitory arrhythmias, and prompt treatment of cardiac failure and shock. In the first 6 months, defibrillation took about 2-3 minutes; with added experience and confidence the time lag has been cut down to about 1 minute. It has been found that unless defibrillation is carried out within 1 minute the chance of recovery is poor. The salvage rate from primary ventricular fibrillation is in the region of 50% in established centres.[5,7,8] Allowing trained staff nurses to deliver electrical shock for ventricular fibrillation will go a long way to achieving this excellent result.

Sinus bradycardia and sino-atrial block are not uncommon arrhythmias, and are often associated with low output or cardiogenic shock. Morphine is a common precipitating factor. Hence if indicated morphia should be given in much smaller doses such as grain 1/8 combined with atropine grain 1/100. These arrhythmias respond well to I.V. atropine or isoprenalin. The former is preferable as it is a safer drug.

Heart block is commonly associated with inferior infarction. Most centres recommend pacing for complete heart block. The mortality is still high in spite of pacing. Initially isoprenaline infusion was used in the unit in doses of 2 mgm. to 500 ml. 5% dextrose solution at a slow rate. Whilst this drug invariably increases heart rate and improves the stroke volume, it is liable to produce ventricular arrhythmias. Hence it should only be used if the patient can be continuously observed and as a temporary measure until insertion of a pacemaker.

Asystole carries a very poor prognosis. Treatment consists of elevating the legs, external thumping and massage, and the use of isoprenalin infusion. Pacing has not been helpful.

Acute right bundle branch block is a sinister development. In many of these patients, the

infarcts were extensive. Those with inferior infarction tended to develop heart block associated with a very high mortality.

It is estimated that a unit or hospital should admit at least 100 cases of acute myocardial patients per year before a coronary care unit is justified.[3] It should be remembered that in order to give intensive care in a C.C.U. to as many patients with suspicious infarcts as possible, one has to over diagnose the condition. Provisions should therefore be made for a wastage of about 30%.[13] The most difficult diagnostic problems are those patients with previous infarction who develop sudden chest pain. Here an urgent estimation of serum creatine phosphokinase (CPK) is particularly valuable in the early diagnosis of A.M.I. as the enzyme becomes elevated within 6 hours from the onset.

In developed countries with a high standard of medical care, a coronary care unit is becoming accepted as part of a good hospital service for the community. Whilst it has been clearly shown that hospital mortalities can be reduced by C.C. Units, the total mortality from the disease in a community has not been shown to be substantially lowered. This is largely due to the fact that a high percentage of myocardial infarction patients die before receiving any form of medical attention.

In developing countries the need for C.C. Units is subject to debate. The question of priorities in the health services should be carefully considered and weighed. However there is a case for supporting such units in teaching hospitals or in well equipped and adequately staffed general hospitals. For apart from the good medical care which a C.C.U. can provide, it has immeasurable value in stimulating medical and scientific thinking among the staff in problems of circulatory physiology and general intensive care. Futhermore it provides much opportunity for a deeper insight into the problems of myocardial infarction and for research in coronary heart disease.

Much thought must be given to the medical and administrative problems and the physical design of a C.C.U. if it is to succeed in its aims. Equipment and its servicing must be reliable, but need not be luxurious. Well trained and dedicated doctors and nurses, and a sound administrative policy, guided by keen leadership remain the cornerstones of a successful coronary care unit.

ACKNOWLEDGEMENT

We wish to acknowledge our sincere thanks to the public and organisations for their generous donations which have made the coronary care unit possible. We also wish to thank the hospital authorities for their support and the nursing staff for continued dedication to the care of the sick. It is hoped that the lessons learnt from the pioneer work of the unit will serve as a guide to others in this region who may wish to introduce such units into their hospital services.

REFERENCES

1. Day, H.W. (1962): "A cardiac resuscitation program." Lancet 82:153.
2. Day, H.W. (1963): "An intensive coronary care area." Dis. Chest, 44:423.
3. Proceedings of The National Conference on coronary care units. Public Health Publication No. 1764, March 1968.
4. Brown, K.W.G., MacMillan, R.L., Forbath, N., Mel'Grano, F. and Scott, J.W. (1963): "Coronary unit—an intensive centre for acute myocardial in farction." Lancet, 2:349.
5. Julian, D.G., Valentine, P.A. and Miller, G.G. (1964): "Disturbances of rate, rhythm and conduction in acute myocardial infarction." Am. J. Med., 37:915.
6. Robinson, J.S., Sloman, G. and McRae, C. (1964): "Continuous electrocardiographic monitoring in the early stages after acute myocardial infarction." M. J. Australia, 1:427.
7. Day, H.W. (1965): "Effectiveness of an intensive coronary care area." Am. J. Cardiol., 15:51.
8. Killip, T. and Kimball, J.T. (1967): "Treatment of myocardial infarction in a coronary care unit." Am. J. Cardiol., 20:457.
9. Goble, A.J., Sloman, G. and Robinson,J .S. (1966): "Mortality reduction in a coronary care unit." B.M.J., 1: 1005.
10. Stock, E., Goble, A. and Sloman, G. (1967): "Assessment of arrhythmias in myocardial infarction." B. M. J., 2:719.
11. Lown, B., Fakhro, A.M., Hood, W.B., Jr. and Thorn, G.W. (1967): "The coronary care unit, new perspectives and directions." J.A.M.A., 199:188.
12. Yu, P.N., Imboden, C.A., Fox, S.M. and Killip, T. (1965): "Coronary care unit. 1. A specialised intensive care unit for myocardial infarction." Mod. concepts Cardiov. Dis., 34:23.
13. Oliver, M.F., Julian, D.G. and Donald, K.W. (1967): "Problems in evaluating coronary care units." Am. J. Cardiol., 20:465.