Résumé Pour démontrer que le liquide céphalo-rachidien (LCR) peut passer le long des nerfs rachidiens, on a injecté une poudre bleue en suspension dans du LCR, dans l'espace lombaire sous-arachnoïdien de porcs et de moutons. Les nerfs rachidiens et d'autres tissus ont été examinés 21 jours plus tard. Des particules de la substance injectée ont été trouvées dans les plexus brachial et lombo-sacré et dans leurs diverses branches, dans les nerfs thoraciques et dans les muscles innervés par ces nerfs ainsi que dans les téguments. Ces résultats et ceux d'expériences similaires et l'observation que l'introduction de particules dans la veine jugulaire n'a permis de les retrouver que dans le poumon permet de conclure qu'il existe une circulation périphérique de LCR le long des nerfs rachidiens.

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Value of a Cardiac Arrest Team in a University Hospital:

Results in a Series of 100 Patients

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THE subject of cardiac arrest and its management is not new. The first successful resuscitation of a patient by external cardiac compression was performed by König of Göttingen in 1892.[1]

That remarkable achievement, however, did not gain wide recognition until 1960, when Kouwenhoven, Jude and Knickerbocker[2] described the method of external cardiac massage as it is now generally performed. Since then the procedure has been widely accepted and, in conjunction with electrical defibrillation and artificial ventilation, has become the modern management of sudden cardiac arrest.[3] Although exact hemodynamic data are not available, evidence based on survival studies indicates the superiority of the closed chest resuscitation procedure over the open chest cardiac massage previously employed.[4, 5]

During the past few years in many hospitals emergency teams have been organized, trained and equipped to perform resuscitation for sudden cardiac arrest.[6-9]

The purpose of this paper is to describe the organization of the cardiac arrest team in the Toronto Western Hospital and to present the results obtained during a period of 24 months.

ORGANIZATION OF THE TEAM

During working hours the team consisted of: staff cardiologist, cardiovascular fellow, senior medical intern on duty, resident in cardiovascular surgery, assistant resident in anesthesia, and nursing supervisor.

After hours (5 p.m. to 8 a.m.), the staff cardiologist and the cardiovascular fellow as a rule did not participate.

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Any responsible member of the medical or nursing staff who suspected that a cardiac arrest had occurred arranged immediately to inform switchboard as to the exact location of the patient with the arrest, and commenced external cardiac massage and mouth-to-mouth ventilation. The operator activated a transistor short-wave radio receiver carried by all members of the team. On the average, members of the team arrived in the area where the arrest had occurred within 3 to 4 minutes. Fracture boards and emergency drug assembly were available on every ward. Monitoring, defibrillating and ventilation equipment was delivered by the team from any of four strategically placed depots in the hospital.

METHODS

The techniques of external cardiac massage and artificial ventilation are well known from previous descriptions and will not be detailed here.[2, 8]

Patients with terminal illness or irreversible brain damage were not resuscitated if these facts were known to the team; however, in a few instances, such patients were treated because the underlying condition could not be appreciated immediately. Debilitated and senile persons were also excluded.

Upon arrival of the team, adequate ventilation was established and the arrest was verified by electrocardiography. Appropriate therapeutic measures were taken to correct the underlying arrhythmia. After successful resuscitation, patients were monitored and attended by a special nurse for varying lengths of time depending upon their clinical condition. On the average, resuscitation attempts, if not successful, were abandoned after half an hour.

MATERIAL

From March 1964 to April 1966, 100 patients developed cardiac arrest and were attended by the resuscitation team. There were 68 males and 32 females. The average age for the entire group was 60.1 years, without significant difference in relation to sex.

For the purpose of this analysis, patients will be subdivided as follows:

Survival: Patients were successfully resuscitated and discharged from hospital.

Initial success: Successful initial resuscitation and restoration of consciousness were obtained for a period longer than one hour, but the patient subsequently died.

Brain damage: In this group, effective hemodynamic function was restored, but the patients acquired severe hypoxic brain damage, remained unconscious and eventually died.

Primary failure: No useful hemodynamic and/or electrical activity of the heart could be established.

RESULTS

The survival and age distribution are given in Table I. It can be seen that there were survivors in all groups. The overall survival rate was 20%, but adequate restoration of cardiac function for at least one hour was achieved in 46% of the patients. One patient survived but was discharged to a nursing home because of permanent brain damage. The rate of initial success in restoring useful hemodynamic function would be even higher (65%) if the repeated episodes of arrest and resuscitation that occurred in some patients were included. (Fourteen patients had two such episodes and one had six.) Although the percentage survival differed among various age groups, the differences were not statistically significant.

TABLE I.—AGE DISTRIBUTION AND RESULTS OF RESUSCITATION IN 100 PATIENTS WITH CARDIAC ARREST

Age in years	*Number of patients*	*Initial success*	*Brain damage*	*Primary failure*	*No. of survivors*	*Survival %*
0 - 40	8	1	1	3	2 + 1*	25.0
41 - 50	11	3	—	6	2	18.1
51 - 60	30	9	3	10	8	23.3
61 - 70	32	3	1	25	3	9.3
71 - 80	14	2	3	6	3	21.4
81 - 90	5	—	—	4	1	20.0
Total.....	100	18	8	54	20	

*One patient was discharged from the hospital with permanent brain damage.

The relationship between the underlying disease process and the outcome of resuscitation is shown in Table II. The majority of patients (71) had arteriosclerotic heart disease, the diagnosis of which was established by clinical and electrocardiographic examination and was confirmed by autopsy in some cases.

Poor results were obtained in eight patients who had chronic rheumatic heart disease. This was probably due to the fact that most of them suffered from severe complications following heart operations, and cardiac arrest occurred *in extremis*.

In the miscellaneous group, four patients had neoplastic disease, two had complications after major abdominal surgery, one had septicemia, one had a subarachnoid hemorrhage due to a ruptured aneurysm, and one was obese and hypertensive.

Both patients with chronic chest disease had severe cor pulmonale with hypoxia.

The relationship between the precipitating factor and survival is shown in Table III. It can

TABLE II.—RELATIONSHIP BETWEEN THE UNDERLYING DISEASE PROCESS AND THE OUTCOME OF RESUSCITATION

Disease	*No. of patients*	*Initial success*	*Brain damage*	*Primary failure*	*Total dead*	*No. of survivors*	*Survival %*
Arteriosclerotic heart disease	71	15	5	35	55	14 + 1*	20.0
Rheumatic heart disease	8	1	—	6	7	1	12.5
Congenital heart disease	2	—	—	2	2	—	0.0
Chronic chest disease	2	1	—	1	2	—	0.0
Poison and trauma	4	—	—	2	2	2	50.0
Miscellaneous	9	1	3	5	9	—	0
Unknown	3	—	—	2	2	1	33.3
No history of illness	1	—	—	1	1	—	0
Total	100	18	8	54	80	19	

*One patient was discharged from hospital with permanent brain damage.

be seen that the highest survival rate was found in patients with complete heart block and Adams-Stokes type cardiac arrest. Of seven patients, four survived (57.1%) and only one patient could not be resuscitated at all (he had an acute myocardial infarction as well). On the other hand, cardiac arrest associated with massive pulmonary embolism caused 70% immediate and 100% overall mortality in this series. Equally poor results were obtained in patients who had congestive heart failure.

By far the most common precipitating factor was acute myocardial infarction; the survival rate in this group was 25%.

TABLE III.—RELATIONSHIP BETWEEN THE PRECIPITATING FACTOR AND SURVIVAL

Precipitating factor	*Number of patients*	*Initial success with and without brain damage*	*Primary failure*	*No. of survivors*	*Survival %*
Myocardial infarction	44	12	21	10 + 1*	25.0
Complete heart block	7	2	1	4	57.1
Pulmonary embolism	10	3	7	—	0.0
Hypoxia	5	2	2	1	
Heart failure	8	2	6	—	
Postoperative complications	6	1	5	—	
Cerebral vascular accident	3	1	1	1	
Trauma	3	1	2		
Hemorrhage	3	1	2		11.7
Miscellaneous	5	1	4		
Anesthesia	2	—	1	1	
Digitalis toxicity	2	—	1	1	
Electrical imbalance	3	2	1	—	
Unknown	11	1	8	2	
	112†				

*One patient was discharged from the hospital with permanent brain damage.

†In some patients more than one precipitating factor existed; therefore, the total number of patients is 112 instead of 100. The overlap was mainly between myocardial infarction and heart failure and myocardial infarction and complete heart block.

These data were further analyzed in an attempt to determine whether the location of the myocardial infarction as indicated by the electrocardiogram affected the prognosis (Table IV).

Twenty patients had anterior myocardial infarction, 11 diaphragmatic and posterior infarction and three subendocardial infarction. Two patients showed no electrocardiographic evidence of recent infarction. It is possible that they had pulmonary embolism, although proof of it is lacking. In eight patients, accurate localization by electrocardiographic criteria could not be determined. The survival rate of 25% in patients with anterior infarction was not statistically different from the 54% observed with diaphragmatic location of the lesion (p 0.05).

The correlation of the electrocardiographically observed rhythm with the survival rate is shown in Table V. The term "asystole" is distinguished from "ventricular standstill". The former denotes complete lack of electrical activity of the heart, the latter lack of ventricular activity only. A "dying heart" pattern is a slow idioventricular rhythm with prolonged intraventricular conduction time and bizarre appearance of the QRST complexes.

TABLE IV.—RELATIONSHIP BETWEEN ELECTROCARDIOGRAPHIC LOCALIZATION OF MYOCARDIAL INFARCTION IN 44 PATIENTS WITH CARDIAC ARREST AND OUTCOME OF RESUSCITATION

Localization of infarction	*Number of patients*	*Initial success with and without brain damage*	*Primary failure*	*No. of survivors*
Anterior and anterolateral	20	7	8	4 + 1*
Diaphragmatic and posterior	11	1	4	6
Subendocardial	3	1	2	0
No infarction pattern	2	0	2	0
Undetermined	8	3	5	0
Total	44	12	21	11

*One patient was discharged from the hospital with permanent brain damage.

Inclusion of the patient in a particular group was arbitrary, since the arrhythmia first observed might have been different had the monitoring been started a moment sooner or later.

Forty-nine patients were observed to have ventricular fibrillation in the initial electrocardiogram; 13 of these patients also developed asystole and in a further 6 a dying heart pattern was subsequently recorded. None of these 19 patients survived and 18 were primary failures. Of the remaining 30 patients who had ventricular fibrillation, 16 survived (53%).

TABLE V.—RELATIONSHIP BETWEEN ELECTROCARDIOGRAPHICALLY OBSERVED RHYTHM IN 100 PATIENTS WITH CARDIAC ARREST AND OUTCOME OF RESUSCITATION

Type of arrhythmia	*Number of patients*	*Number of arrests*	*Subsequent arrhythmia**					*No. of survivors*	*Survival %*
			CAS	*DH*	*VS*	*VF*	*VT*		
Ventricular fibrillation	49	56	13	6	—	4	1	15 + 1*	31.0
Asystole	20	22	3	2	1	4	—	0	0
Complete heart block—ventricular standstill	7	10	—	—	—	3	—	4	57.1
Dying heart pattern	9	9	—	2	—	2	—	0	0
Ventricular tachycardia	1	1	—	—	—	—	—	0	0
Unknown	20	—	—	—	—	—	—	3	1.5
	106†								

†Five patients had two arrests and one of these had three, each time qualifying for a different group; therefore total count of patients is 106 instead of 100.

*CAS = cardiac asystole; DH = dying heart pattern; VS = ventricular standstill; VF = ventricular fibrillation; VT = ventricular tachycardia.

**One patient was discharged from the hospital with permanent brain damage.

In 20 patients in whom electrical asystole was initially recorded, the outcome was invariably fatal.

A dying heart pattern was initially recorded in nine patients; they were all primary failures.

Ventricular standstill was observed in seven patients, of whom four survived (57%). The three patients who died also had ventricular fibrillation; two of them were over 80 years of age.

COMPLICATIONS OF RESUSCITATION PROCEDURE

Rib fractures were common and almost the rule in older patients, but they were considered routine minor complications. One patient had a ruptured liver. In two patients, hematomas of the anterior wall of the left ventricle were demonstrated at autopsy. One of these two patients also had hemopericardium. This likely resulted from laceration of coronary vessels during intracardiac injections: It is possible that the incidence of hematomas, related to intracardiac drug administration or to too vigorous cardiac compression, was in fact higher, but went undiscovered because of the low autopsy rate (20%).

DISCUSSION

The overall survival rate in the present series compares favourably with the rates published by others (see Table VI). With the exception of the outstanding 70% survival rate reported by Kouwenhoven, Jude and Knickerbocker, the percentage of patients discharged from hospital varied between 6% and 16%.

We believe that the only criterion of successful resuscitation from cardiac arrest should be a live and neurologically competent patient capable of leaving the hospital. It is difficult to agree with the opinion that resuscitation has been successful if adequate hemodynamic function has only temporarily been restored by external cardiac compression.[14] If this criterion had been accepted in the present series, the success rate would have been 65%. Only one patient left the hospital with permanent brain damage and with little hope of significant improvement.

TABLE VI.—COMPARISON OF THE RESULTS OF CLOSED CHEST RESUSCITATION FOR CARDIAC ARREST

Source	*No. of patients treated*	*No. of survivors**	*Survival %*
Present series	100	20	20
Kouwenhoven and Jude[2]	20	14	70
Johnson[6]	51	5	10
Portal *et al.*[10]	18	3	11
Klassen *et al.*[11]	126	17	13
Kaplan and Knott[12]	100	6	6
Minogue, Smessart and Grace[13]	29**	3	10
Himmelhoch *et al.*[14]	65	4	6
Lillehei *et al.*[15]	200	33	16

*Survival: patients who were successfully resuscitated and discharged from hospital.

**Myocardial infarction cases only.

In our experience, survivors were found in all age groups. It seems, therefore, that one should not exclude patients from the potential benefit of resuscitation on the basis of age alone. The sex of the patients did not have any bearing on the outcome. These observations are in agreement with data reported by Mower, Miller and Nachlas[16] in relation to patients with myocardial infarction.

No conclusion could be reached about the relationship between the underlying disease process and the survival rate after the data had been submitted to statistical analysis (Fisher's exact test).[17] A review of the factors precipitating cardiac arrest and their relation to survival indicated that the chance of successful resuscitation of patients with myocardial infarction was not different from that of any other group.

In their analysis of 138 cases of death due to myocardial infarction, Mower, Miller and

Nachlas[16] estimated that 56% of the deaths were due to sudden arrhythmia. Of all the deaths, 79% occurred within five days of admission, while 79% of "rhythm" deaths had premonitory electrocardiographic evidence of increased ventricular irritability. Yater and his associates[18] in a large series of cases of myocardial infarction demonstrated that of those who died, 83.3% did so during the first day after admission and 52.9% within the first hour after the onset of their symptoms. It seems clear that such patients run a high risk of developing sudden cardiac arrest. It is our opinion that continuous electrocardiographic monitoring in an intensive care area, with readily available resuscitation equipment, would markedly speed up emergency treatment and additionally increase the survival rate.

An analysis of the electrocardiograms in our patients indicated that the most frequent location of the infarct was anterior and anteroseptal; however, no significant difference in the survival rate could be demonstrated in relation to the location of the infarction.

Patients with complete heart block did have a significantly better prognosis (p 0.004) than all the others except the myocardial infarction group, which exhibited the same chances of survival. A relatively good prognosis in cardiac arrest due to complete heart block was reported by Portal *et al.*[10]

Poor results were obtained in patients with congestive heart failure. It is possible that the depletion of myocardial catecholamines and impairment of catecholamine uptake by the myocardium, which occurs in congestive heart failure,[19] may account for the lack of responsiveness to drugs and the inadequacy of myocardial contractility.

From the analysis of the arrhythmias which had occurred in this series of patients, one could conclude that asystole and the dying heart pattern carried an extremely poor prognosis. Inability to restore effective cardiac function in patients displaying the dying heart pattern suggests that this form of arrhythmia probably denotes an irreversibly damaged myocardium, incapable of contraction. Moreover, the occurrence of asystole or dying heart pattern may be considered as a guide to the termination of resuscitative efforts.

Summary The organization and work of the cardiac arrest team in the Toronto Western Hospital is described. Over a period of two years, 100 patients were treated by the cardiac resuscitation team. Of these 100 patients, 20 were discharged well from the hospital. The longest period of follow-up was 3½ years and that patient was found to be well and back at work. The most common factor precipitating the arrest was myocardial infarction and the most favourable electrocardiographic pattern for resuscitation was complete heart block. No patient with asystole was successfully resuscitated. Cardiac arrest secondary to Stokes-Adams seizure had a relatively better prognosis than other types of arrest. There was no correlation between the survival rate and the age or sex of the patient, the underlying disease, the precipitating factor or the location of the myocardial infarction. The establishment of an electrocardiographic diagnosis and the speed of resuscitation are stated to be of paramount importance. The 20% survival rate is a good indication of the great value of such a team in any hospital.

Résumé Les auteurs rendent compte de l'organisation et du travail effectué par l'équipe de réanimation cardiaque au Toronto Western Hospital. Cette équipe a traité 100 patients sur une période de deux ans. De ces 100 malades, 20 ont quitté l'hôpital en bonne santé. La période de post-observation la plus longue a été de 3½ ans. Le malade ainsi observé était bien et avait repris son occupation. Le facteur qui a déclenché le plus couramment l'arrêt cardiaque a été l'infarctus du myocarde et le tracé électrographique le plus favorable pour la réanimation était la fibrillation ventriculaire. Aucun des malades présentant de l'asystolie n'a pu être réanimé. L'arrêt cardiaque secondaire à une crise d'Adams-Stokes avait un pronostic relativement plus favorable que les autres types d'arrêt cardiaque. On n'a pu mettre en évidence de corrélation entre le taux de survie et l'âge ou le sexe du malade, ni avec la pathologie profonde, ni avec le facteur déclenchant ou la localisation de l'infarctus. On considère comme des éléments extrêmement importants le fait de disposer d'un diagnostic électrocardiographique et la rapidité de la réanimation. Le taux de survie de 20% indique bien la grande valeur qu'a pareille équipe dans tout hôpital.

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