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THE CARDIAC ELECTROGRRAM IN REVERSIBLE MYOCARDIAL ISCHEMIA

F. Hakami, M.D. I.L. Rubin, M.D.

The recording of cardiac electrograms is a technique used to study electrical activation of the heart. Recently it has been used during cardiac surgery delineate areas of myocardial damage. (1) In the method developed by Kaiser and his co-workers, the experimental production of myocardial infarction in dogs resulted in a decrease in amplitude and an increase in duration of the bipolar electrograms recorded from the areas of infarction. duration of the bipolar electrograms recorded from the areas of infarction. Identical findings were obtained in recordings from inert areas of myocardium in twelve patients undergoing cardiac surgical procedures for myocardial revascularization, resection of ventricular aneurysms, resection of akinetic areas of left ventricle and infarctectomy. This method was said to be reliable and reproducible in differentiating inert from viable tissue.

Our group has long been interested in the phenomenon of the transient pathological Q wave observed in such diverse clinical states as myocardial ischemia without infarction, hypoglycemia, hyperkalemia and acidosis.(2-11) In a previous report we described the experimental production of transient Q waves in the electrocardiograms of dogs during myocardial ischemia.(11) In the process of studying this further, we recently examined the bipolar electrocardiograms obtained from dogs following temporary coronary artery ligation. These were identical to those observed in inert areas by Kaiser et al. (1) However, the abnormal electrograms observed in these experiments were completely reversible upon restoration of coronary flow with release of the occluding ligature.

Assistant Professor of Cardiothoracic Surgery.
Pahlavi Medical Center School of Medicine, University of Tehran.

METHODS — Six mongrel dogs were anesthetized with intravenous sodium pentobarbital (30 mgs./kg), and intubated with a cuffed endotracheal tube. Respiration was maintained with a pump respirator. A left lateral thoracotomy was carried out and the heart exposed in a pericardial cradle. Loose ligatures were applied to branches of the left anterior descending coronary artery. Electrode plaques,(12) each containing five separate silver electrodes 2 mm apart leading to individual teflon coated wires, were sutured to the epicardium using 5-0 silk. These were positioned in close proximity to the coronary ligature and at more distal sites. Electrograms and standard electrocardiograms were monitored on a switched beam oscilloscope (Electronics for Medicine) and recorded on photographic paper at various paper speeds. The preamplifier filters were set for frequencies of 0.1-200 cycles/second. Following determination of the control electrographic and electrocardiographic configuration, the coronary ligature was tightened and further recordings made at various subsequent time intervals. The ligature was then loosened, and the effect on the electrograms observed.

RESULTS — In all six experiments, the ischemic zone produced by coronary ligation was easily distinguished by the gross appearance of pallor and cyanosis from adjacent non-ischemic myocardium. In five of the experiments, the bipolar electrograms recorded from the ischemic zone differed from controls and showed widening of the complexes, decrease in voltage, and changes in configuration indicating an altered pathway of depolarization. These changes were similar to those previously reported (1) to be characteristic of an electrically inert myocardium. In these five experiments, following release of the coronary ligature, the electrograms returned completely to their previous "normal" configuration. In one experiment, ventricular fibrillation occurred shortly after release of the coronary ligature. Numerous DC countershocks were followed by recurrence of ventricular fibrillation, and finally death of the animal from irreversible fibrillation. Prior to the onset of fibrillation, the configuration of the electrographic complexes had changed towards normal in that voltage had increased and duration of the complexes had decreased.

Fig. 1 shows the changes observed in an experiment in which the period of ligation was four minutes. During the control period (A) predominantly upright complexes with an Rs configuration was noted in the bipolar electrograms (E1 and E2). The S-T segments were isoelectric. Following ligation, progressive alterations in the configuration of the complex electrogram occurred, particularly in E-2, located within the ischemic area. The QRS complexes showed only minute potentials. In E-1 at the periphery of the ischemic area, the duration of the QRS complex was markedly prolonged and the S-T segment elevated. Corresponding changes were not seen in the electrocardiogram. Following the removal of the ligature there was a return to the control configurations. (1C) Figure 2 shows findings in another experiment, similar to these. In E-2 at the center of the ischemic area, the QRS complex lost virtually all voltage and the S-T segments were elevated.

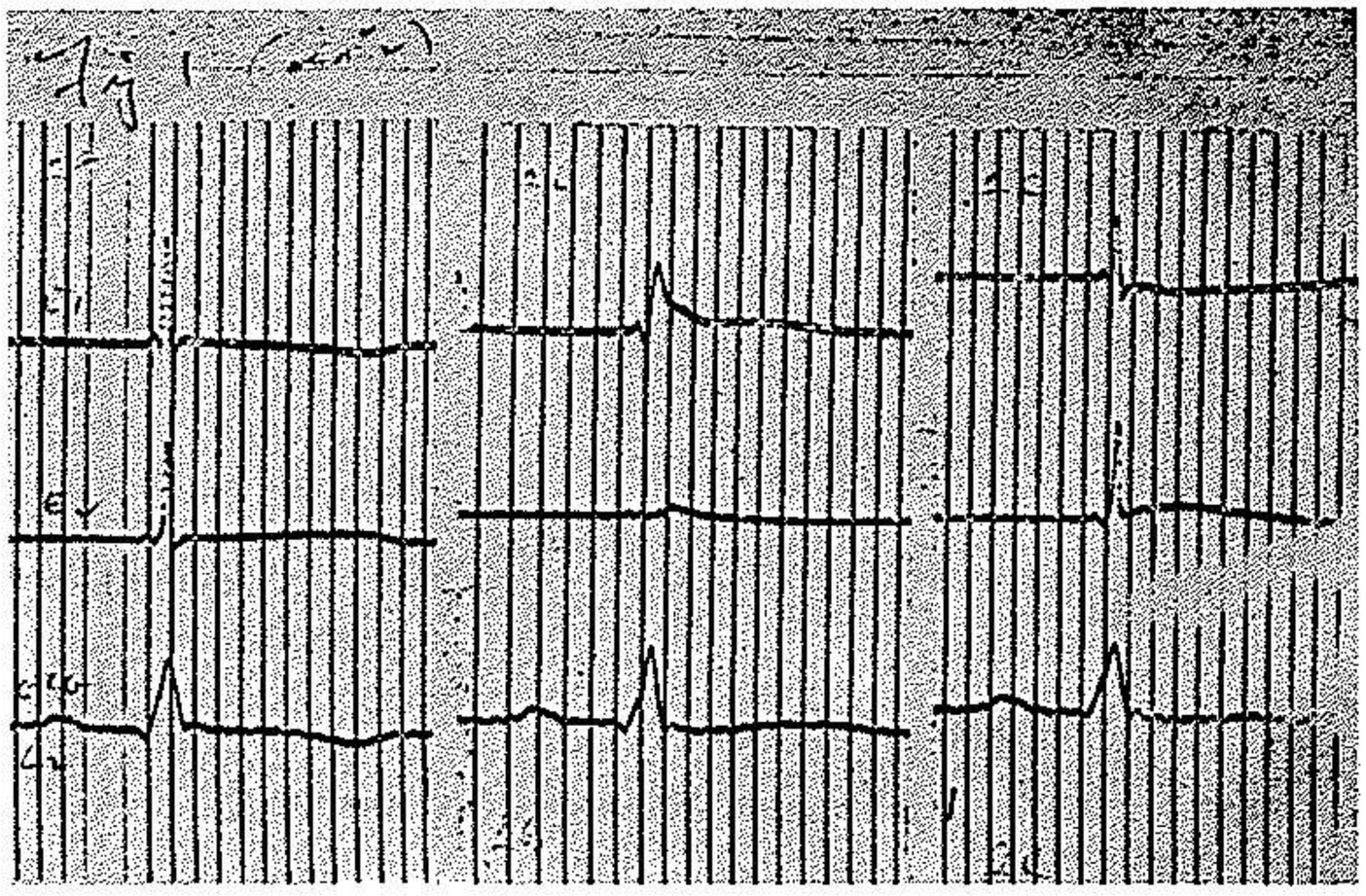

Fig. 1 A. Prior to coronary ligation.

B. After 4 minutes of coronary artery ligation.

C. Following removal of the coronary ligature.

E-1 is a bipolar electrogram taken at the periphery of the ischemic areas and E-2 at its center. The bottom tracing is a lead II electrocardiogram. See text. Note the marked but reversible changes in E2.

E-1 at the periphery of the ischemic area showed reduced voltage and significant widening of the QRS complex. Following removal of the ligature, C, the electrograms returned to control amplitude and form. These serial changes were again not reflected in the electrocardiographic lead.

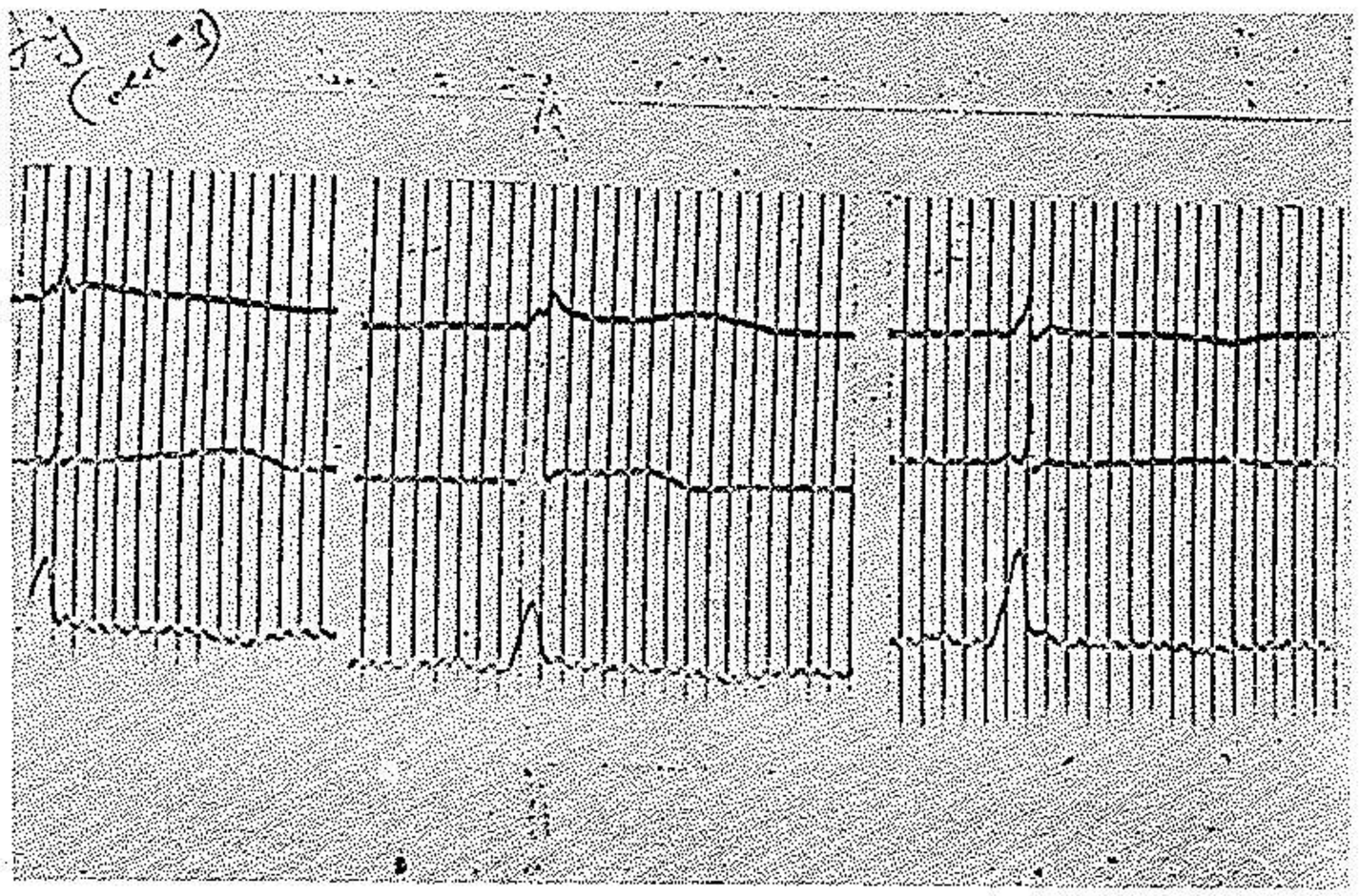

Fig. 2 See caption for fig. 1. Reversible changes are again noted on the electrogram situated in the center of the transient ischemic area.

DISCUSSION — In both, there was a diminution in the voltage and increased duration of the electrographic complexes, as well as changes in configuration.

The development of modern cardiac surgical techniques has made it important to be able to delineate accurately the extent of an area of myocardial damage. Earlier approaches to this problem were to utilize the injection of coronary arteries with dyes such as methylene blue (13) of fluorescein (14), which differentially stained living and damaged tissue. More recently, Kaiser and his co-workers (1) demonstrated the feasibility of localizing small areas of myocardial damage by an electrophysiological technique, the

electrocardiogram. This method was felt to be superior to the dye technique used for the same purpose. They also showed the superiority of bipolar to unipolar electrograms since the latter may occasionally show Q waves over normal tissue adjacent to abnormal tissue. In their studies, they were concerned primarily with areas of permanent myocardial damage.

Our experiments demonstrate that transient and reversible myocardial ischemia can result in changes in the cardiac electrogram which are identical to those previously observed in recordings from areas of permanent myocardial damage.

The transient nature of these changes should be taken into consideration when interpreting the bipolar electrogram in clinical situations. An analogous situation occurs in the clinical electrocardiogram, where an abnormal Q wave is usually indicative of permanent damage or necrosis. Less commonly abnormal Q waves have been recorded in anginal attacks, (2) myocardial ischemia, (3,4) hypoglycemia and shock (5), hyperkalemia (6) phosphorous poisoning (7) and acute pancreatitis. (8) Also transitory abnormal Q waves have been produced experimentally in the dog by temporary coronary artery ligation. (9-11) Abnormal Q waves develop when there is electrical inertness or silence in a significant area of heart muscle. The usual cause of such changes is necrosis of heart muscle or its replacement by tumor, amyloid or fibrous tissue. The Q wave may be transitory in myocardial ischemia and disappear with restoration of normal cellular electrical activity. When ischemia leads to cellular death, the abnormal Q wave is permanent. The changes which have been observed in the bipolar electrogram recorded from areas of myocardial ischemia or necrosis correspond to the changes in electrical activation represented by the electrocardiographic Q wave of myocardial ischemia or infarction.

Changes found on the electrogram at cardiac surgery may be due solely to cardiac ischemia and do not necessarily indicate permanent muscle death.

SUMMARY —

Bipolar cardiac electrograms were obtained in dogs from ischemic areas following temporary coronary artery ligation. Characteristic alterations from the controls were observed, including increase in duration, decrease in amplitude and alterations in configuration. These changes were found to be completely reversible upon restoration of coronary flow. The bipolar electrogram has been recommended for the delineation of areas of permanent myocardial damage from normal tissue during cardiac surgery. Interpretation of such bipolar electrograms as indicating permanent myocardial damage must be approached with appropriate caution.

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