Electrocardiography

MICHAEL BERNREITER, M.D., F.A.C.P.

Assistant Clinical Professor of Medicine, University of Kansas Medical School; Chief of Electrocardiography, St. Mary's Hospital, Kansas City, Missouri; Fellow of the American College of Cardiology and Fellow of the American College of Chest Physicians

Philadelphia · Montreal

J. B. LIPPINCOTT COMPANY

Distributed in Great Britain by
Pitman Medical Publishing Co., Limited, London

Library of Congress Catalog Card No. 58-6215

Printed in the United States of America

Electrocardiography

Preface

Interest in electrocardiography as an effective clinical tool seems to be increasing each year. The increased interest has become quite apparent to me as it has been my privilege to teach the subject to medical students, interns and practicing physicians for more than a decade.

My purpose in this book is to outline the fundamental aspects of electrocardiography as they are encountered in everyday practice. Only the most basic physical principles necessary to understand the electrical phenomena of electrocardiography are discussed. Without these basic principles, interpretation of tracings would be reduced to "pattern memorization," an unscientific approach which overburdens and discourages the student. Schematic diagrams are shown throughout the text to clarify the electrical phenomena responsible for certain electrocardiographic patterns. The discussion of cardiac arrhythmias, myocardial infarction, bundle branch block and hypertrophy emphasizes, for the sake of clarity, the elementary findings in these conditions.

The book has been directed toward the needs of the medical student, the general practitioner and the internist. It also is meant to supplement the graduate courses in electrocardiography given yearly at St. Mary's Hospital and The General Hospital of Kansas City, Missouri.

Much of the data presented were derived from personal experience with students and patients. Almost all electrocardiograms shown in the chapters of hypertrophy, myocardial infarction and cor pulmonale are from patients who came to autopsy and in whom the electrocardiographic diagnosis was verified by necropsy findings. However, in bedside diagnosis it is important that the student realize that electrocardiography is only an adjunct in the final diagnosis and not a substitute for careful clinical observation.

Most of the electrocardiograms shown in the text are original reproductions from the electrocardiographic department of St. Mary's Hospital, and I wish to extend my sincere thanks to the Sisters and the Staff of St. Mary's Hospital for their considerate co-operation.

I am indebted to many students who have encouraged me in writing this book; also, to many authors whose texts have been consulted. My thanks also go to Mrs. Mary L. Johnson and Miss Virginia L. Stack, who have taken almost all tracings shown in this manuscript; and particularly to my secretary, Miss Virginia Wittwer, who typed and assisted in preparing the text.

Last, but not least, I wish to thank my publishers, and particularly Mr. J. Brooks Stewart, their Medical Editor, for his kind assistance and many helpful hints.

I hope that this text will serve a useful purpose for those interested in electrocardiography.

MICHAEL BERNREITER, M.D.

Electrocardiography

Contents

1

Basic Electrical Phenomena, Depolarization, Repolarization

Muscle contraction is associated with production of electrical current which can be studied with a measuring instrument such as a galvanometer. No electric flow is recorded as long as the muscle is in the resting state. All the positive ions are on the outside of the cell membrane, and the negative ions are on the inside. Migration of these ions is prevented by the cell membrane which has a high electrical resistance (Fig. 1). If the electrode of a galvanometer is attached to a fully resting muscle no electrical potential will be registered, and there will be no deviation from a straight (iso-electric) line.

A muscle may be stimulated electrically, chemically or mechanically. Such stimulation will produce a change of membrane permeability permitting reorientation of the ions. Such a muscle is in the state of depolarization. The process of depolarization once initiated will spread rapidly through the entire length of the muscle without additional stimuli. Activation may begin at any point. Wherever activation (depolarization) begins, the nonpermeability of the membrane is disturbed, and the negative ion now appears on the outside of the cell membrane. There is now a current flowing because negative and positive ions are present on the outside of the cell membrane. The positive ion is facing the direction of the current, and the negative ion is following it (Fig. 2). As soon as the entire muscle strip is depolarized (electrically negative) electrical activity again ceases for a short period

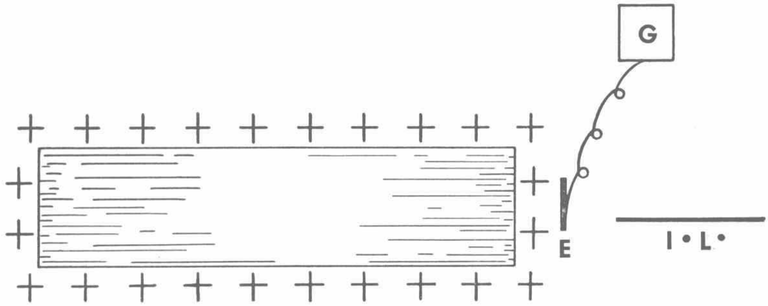


FIG. 1. Inactive resting cell. E: Electrode. G: Galvanometer (EKG machine). I.L.: Iso-electric line. In a resting muscle all the positive ions are on the outside of the cell membrane. There is no difference in electrical potential, and no electrical current is flowing. Electrode E facing the right side of the resting muscle and connected to a galvanometer (G) will record no current and the iso-electric line (I.L.) remains undisturbed.

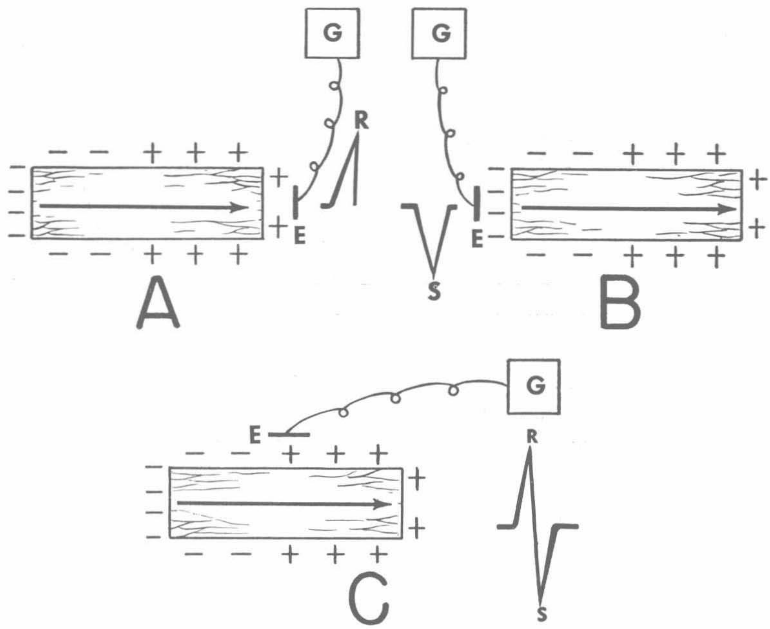


FIG. 2. Depolarization. (A) The muscle strip is stimulated from the left, and depolarization proceeds from left to right in the direction of the arrow. The activated (depolarized) left end of the muscle becomes immediately electrically negative, while the right end of the muscle is still resting and electrically positive. There is now a difference of electrical potentials (negative and positive ions), and an electrical current is flowing. Electrode E faces the positive side of this current, and the galvanometer G will record a positive deflection (R wave).

(B) The same muscle strip is stimulated again from the left, but now electrode E is facing the negative side of the current and therefore will write a negative deflection (S wave).

(C) Again the muscle strip is activated from the left. Electrode E facing the center of the muscle will first write a positive then a negative deflection (RS complex).

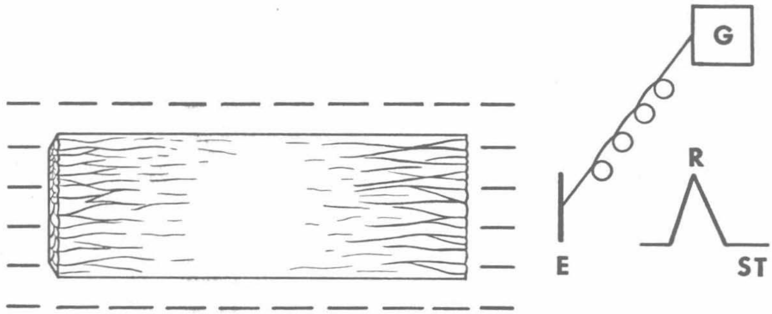


FIG. 3. The above muscle strip is completely depolarized. During the process of depolarization the R wave was recorded (see Fig. 2 A). With the completion of depolarization the entire outer surface of the muscle becomes electrically negative; the flow of electrical current ceases, and the R wave returns to the iso-electric line (ST). From these demonstrations we learn that a completely depolarized muscle, like a completely resting muscle, produces no electrical current.

of time (Fig. 3). The electrical potential has disappeared because all the ions on the outside of the muscle membrane are now electrically negative. The galvanometer will record no electrical potential resting on the iso-electric line. This state of contraction cannot long persist, and the muscle will start to relax (repolarize). While the normal skeleton muscle will repolarize in the same direction in which it was depolarized, producing an inverted T wave, the heart muscle repolarizes in the opposite direction, producing an upright T wave (Fig. 4). Depolarization of the myocardium begins in the subendocardial area and proceeds to the subepicardial area. Repolarization travels in the opposite direction from epicardium to endocardium. The process of repolarization is easily disturbed. Even in a skeleton muscle the application of cold or pressure in that part of the muscle which was first activated will prevent the initiation of repolarization in this area. As a result of the interference repolarization will start at the other end of the muscle and therefore travel in the opposite direction of depolarization. The pressure exerted against the subendocardial myocardium during systole is perhaps the most logical explanation as to why repolarization normally starts in the subepicardial region and proceeds from there to the endocardium.

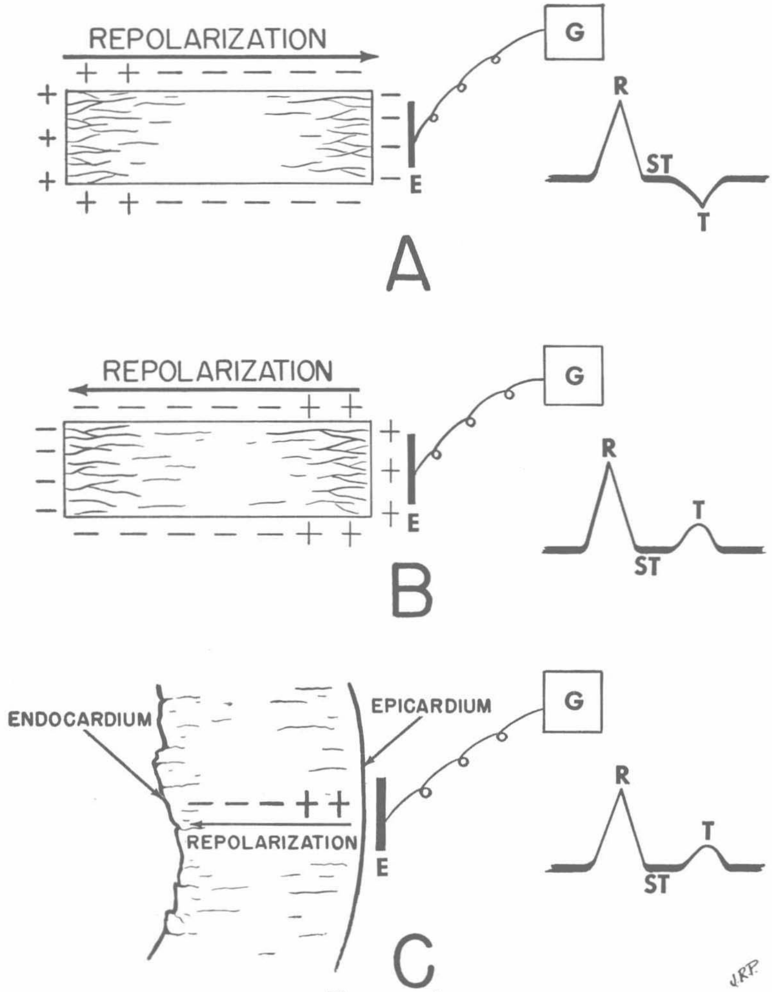
INTRINSIC AND INTRINSICOID DEFLECTION

An electrode in direct contact with the myocardium, as in Figure 5, will record a positive deflection (R) as long as depolarization is in progress from endocardium to epicardium. As soon as the excitatory process arrives under the electrode, the electrical potential is exhausted, and the galvanometer needle will return to the iso-electric line. This is the intrinsic deflection. It is a convenient and accurate method of measuring the time it took for depolarization to travel from endocardium to epicardium. Because in clinical electrocardiography the electrode is not in direct contact with the myocardium but rather with the chest wall, this deflection is called the intrinsicoid deflection.

FIG. 4. Repolarization (return to the resting state). (A) The strip of skeleton muscle shown has been completely depolarized from left to right. During this process electrode (E) was facing the positive end of the electrical current, and the galvanometer (G) recorded a positive deflection (R). With completion of depolarization the flow of electrical current ceased and the R wave returned to the iso-electric line (ST). The outer surface of the muscle remained negative throughout while the muscle was in a state of contraction. No electrical current was flowing and the iso-electric ST segment was written. Now the muscle starts to return to the resting state (repolarize) in the same direction in which it was activated, namely from left to right. The left end of the muscle will be first to become positive at a time when the right end is still activated and electrically negative. An electrical current again is flowing. Electrode (E) facing the right side of the muscle is exposed to the negative potential of this current and therefore will write a negative deflecion (T). The T wave then represents repolarization (return to the resting state).

(B) The muscle strip was as in example A depolarized from left to right. The R wave is the result of this electrical current. The ST segment, iso-electric like in the previous experiment (A), is written while the entire muscle is in a state of contraction (electrically negative). We shall now apply pressure to the left end of this strip. This will prevent repolarization from starting in this area. Then the muscle will start to relax from right to left. The right end of the muscle will be first to become positive. During this process of repolarization, electrode (E) is exposed to the positive end of the current and will write a positive deflection (T wave). We learn from this experiment that repolarization, unlike depolarization, is disturbed easily. Slapping one end of the muscle strip, pinching it, or applying ice water will prevent beginning of repolarization in this area.

(C) A section of myocardium is shown. Depolarization from endocardium to epicardium has been completed. An electrode (E) facing the epicardial (outside) area of the myocardium has recorded a positive deflection (R) wave. The muscle remains in a state of contraction (electrically negative) for a short period of time and an iso-electric ST segment is written. Because there is now considerable pressure against the endocardium, this strip of myocardium will start repolarizing from epicardium to endocardium (from outside to inside) and in the opposite direction of depolarization. During this process, electrode (E) is facing the positive end of the current and therefore will write a positive deflection (T wave).



REPOLARIZATION
G
R
ST
T
E
A
REPOLARIZATION
G
R
T
ST
E
B
ENDOCARDIUM
EPICARDIUM
G
R
T
ST
REPOLARIZATION
E
C

FIGURE 4

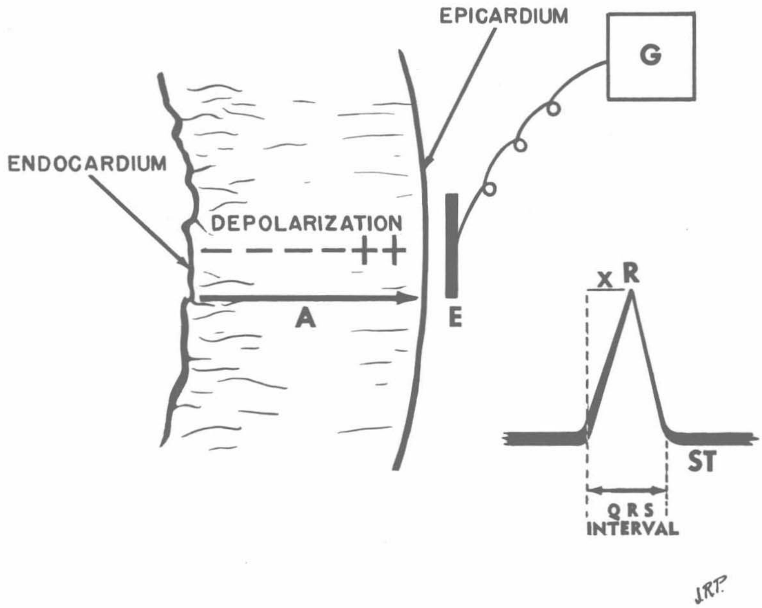


FIG. 5. Intrinsicoid deflection. Depolarization travels from endocardium to epicardium as represented by Arrow A. Electrode E facing the positive end of the current will record a positive deflection (R wave). As soon as the forces of depolarization arrive under electrode E, the electrical current will cease to flow, and the galvanometer needle will return to the iso-electric line (ST segment). This is the intrinsicoid deflection, and X represents the time it took for this force to travel from endocardium to epicardium in this particular position. The QRS interval is the time it took the entire myocardium to be activated.