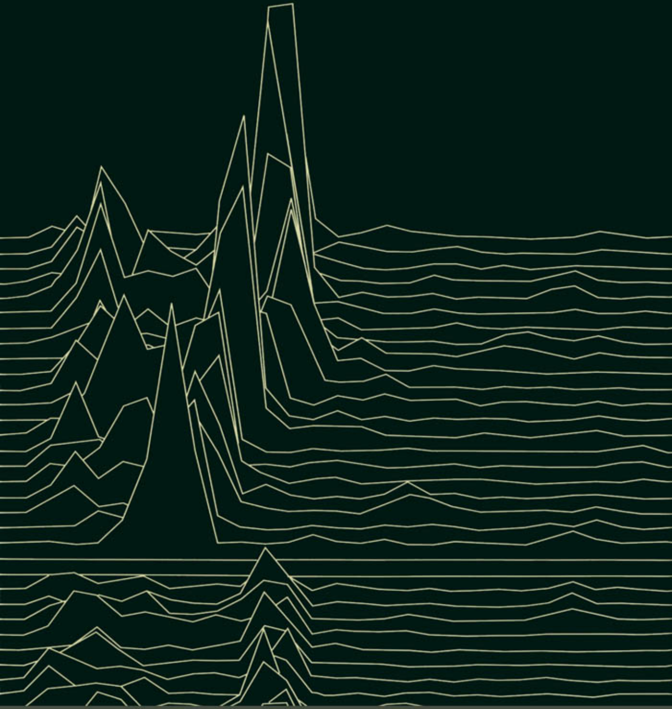
HANDBOOK OF ELECTROGASTROGRAPHY



KENNETH L. KOCH AND

ROBERT M. STERN

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Preface

Electrogastrography refers to the methods of recording electrogastrograms (EGGs). EGG rhythms reflect the gastric pacesetter potentials or slow waves of the stomach. Pacesetter potentials are crucial electrical depolarization and repolarization waves because they control the timing and propagation velocity of gastric peristaltic contractions. Gastric peristaltic contractions are responsible for mixing and emptying the foodstuffs that are ingested throughout the day. In humans, the gastric pacesetter potential is approximately 3 cycles per minute (cpm). Thus, the 3-cpm EGG signals are noninvasive recordings of the electrical activity of the stomach in health.

During the past 20 years, there have been important advances in the understanding of stomach electrical and contractile activity. It has also become clear that the normal electrical rhythm of the stomach may become very disordered. *Gastric dysrhythmias* are abnormalities of gastric myoelectrical activity. These disturbed electrical rhythms are recorded in the EGG signal. Abnormally fast electrical rhythm are termed *tachygastrias,* and abnormally slow rhythms are described as *bradygastrias.* Gastric dysrhythmias are common in the clinical settings of nausea that occur during motion sickness, chemotherapy, and the nausea of pregnancy. Gastric dysrhythmias are frequently present in patients with functional dyspepsia, unexplained nausea, and diabetic, idiopathic, and postsurgical gastroparesis. Furthermore, correction of gastric dysrhythmias with drug therapies or electrical stimulation is associated with improvement in nausea and vomiting. In many respects, the recording of the EGG is analogous to the recording of electrocardiogram. Thus, there has been increasing interest in electrogastrography and in the diagnostic value of EGG patterns.

The purpose of this handbook is to present the physiological basis for electrogastrography with a series of diagrams, illustrations, and examples of actual EGGs and analyses. The authors have more than 60 years of combined experiences in evaluating patients with a wide variety of nausea and vomiting syndromes and in studying healthy subjects in a variety of psychophysiological experiments. Thousands of EGG recordings have been recorded and studied by the authors. The EGGs were recorded from diverse patients ranging from diabetic patients with gastroparesis to patients with dysmotility-like dyspepsia symptoms and unexplained nausea. EGGs from healthy subjects who became nauseous in various controlled studies are also described. The handbook is not meant to be an exhaustive treatise on electrogastrography. Rather than reviewing the contributions of many investigators, the handbook describes the practical aspects of how to record excellent EGGs and the methods available for analyzing, quantifying, and interpreting the EGG recordings. The authors also acknowledge the work of Kent Sanders and colleagues who contributed chapter 2 on the basic electrical properties of the stomach.

With increasing interest in the EGG from researchers and clinicians, this book should become a helpful reference for the interpretation of normal and abnormal EGG recordings. An EGG recording device and software analysis system have been cleared by the Food and Drug Administration and are available commercially. One of the authors (K. L. Koch) has a financial interest in the company that manufactures this medical equipment. The EGG is a unique and noninvasive diagnostic test for gastroenterologists in multidisciplinary group practices, in clinical gastrointestinal motility centers, and in research laboratories. EGG recordings will be of interest to internists and family medicine physicians who treat patients with dyspepsia or gastric dysfunction. Diabetologists may have a particular interest in EGG patterns in patients with dyspepsia symptoms and type 1 or 2 diabetes. Relationships among gastric neuromuscular function, plasma glucose levels, and insulin therapy are becoming more appreciated and integrated into diabetes care. The handbook will also be a reference source for fellows in gastroenterology and researchers with an interest in gastric myoelectrical activity. In addition, we hope the handbook will serve as a primer for researchers in fields such as psychosomatic medicine and psychophysiology who are in need of a noninvasive method for quantifying gastric myoelectrical activity.

Winston-Salem, North Carolina K. L. K.
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Brief History of Electrogastrography

During the first half of the twentieth century, before the availability of computerized literature searches, scientists who were working independently often discovered similar measures, phenomena, or relationships. The electrogastrogram (EGG) was discovered independently by at least three investigators: Walter Alvarez, a gastroenterologist; I. Harrison Tumpeer, a pediatrician; and R. C. Davis, a psychophysiologist.

On October 14, 1921, after considerable experimentation with rabbits at the University of California in San Francisco, Walter Alvarez[1] recorded the first human EGG. Figure 1.1 shows this EGG, which was recorded from an elderly woman with an abdominal wall hernia. The woman was so thin that Alvarez could observe gastric contractions of 3 min in the upper abdomen that corresponded to the 3 cycles/min (cpm) electrical waves that are clearly seen in the EGG recording. Alvarez did not publish additional studies with the EGG during his long and productive career, probably because of the technical difficulties inherent in recording such a weak signal before the development of good vacuum tube amplifiers.

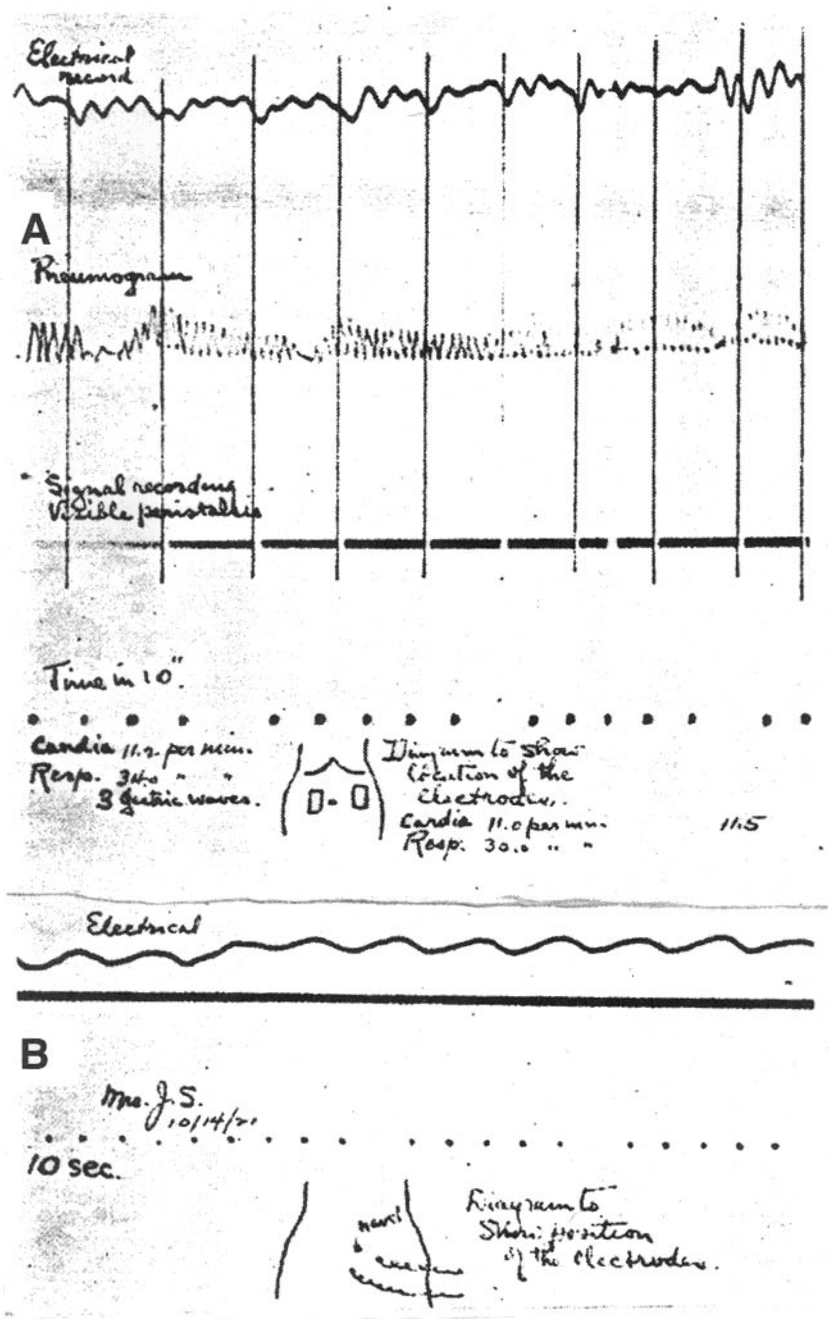

Figure 1.1. The first human electrogastrogram (EGG) recorded from a woman whose abdominal wall was so thin that her gastric peristalsis was easily visible. (*A*) EGG (top tracing), respiration, and markers indicating when visible peristalsis was observed. Note the temporal correspondence between the EGG signal and these markers. (*B*) EGG (the tracing just above the horizontal line) from a different electrode placement that is shown in the figure. (Reprinted with permission from Alvarez, 1922.)

I. Harrison Tumpeer, a pediatrician working at Michael Reese Hospital in Chicago, reported in 1926[2] that while he was attempting to record the EGG, "Alvarez of California published his results." In a subsequent publication,[3] Tumpeer successfully recorded the EGG from a 5-week-old child who had pyloric stenosis. Tumpeer and his coworkers selected this particular subject because they could observe gastric contractions by simply watching the surface of the skin over the abdomen. Figure 1.2 shows a portion of this EGG. Tumpeer described the EGG as looking like an electrocardiogram (ECG) with a slowly changing baseline. Tumpeer mentioned that cardiologists in 1926 often noted a changing baseline in ECG recordings that they could not explain. Thus, the EGG had been recorded, but perhaps not recognized as such, since the time of the first ECG at the turn of the twentieth century. Tumpeer used limb leads to record his EGG (not abdominal leads) because of his concern that each gastric contraction caused physical displacement of the skin over the child's abdomen. Subsequent studies[4] showed that simultaneous recordings from limbs and abdomen are similar except that the amplitude of the EGG is greatly reduced from recordings from the limb leads.

R. C. Davis, a psychophysiologist, began a series of exploratory studies with the EGG in the mid-1950s. Because he was not aware of the earlier EGG work of Alvarez or Tumpeer, he was the third person to independently discover the EGG. Davis was primarily interested in the interactive effects of psychological and physiological factors on gastric functioning. Davis and colleagues published two papers on the EGG before his untimely death in 1961, papers that stimulated several other investigators to begin conducting EGG research.

In 1957, Davis and coworkers[5] described their attempt to validate the EGG using simultaneous recordings from needle electrodes, a mine detector that picked up the movements of a steel ball in the subject's gastrointestinal tract, and the EGG. They used needle electrodes that were insulated except at the tip so that they could rule out cutaneous tissue as the source of the EGG signal. Figure 1.3 shows a portion of one such simultaneous recording from Davis' laboratory.

In 1959, Davis and his coworkers[6] described validation studies of the EGG using swallowed balloons; Figure 1.4 shows simultaneous records obtained from EGG surface electrodes and an intragastric balloon, showing correspondence between the EGG recording from the upper left quadrant of the abdomen (top tracing) and the recording from the balloon (bottom tracing). In this same study,

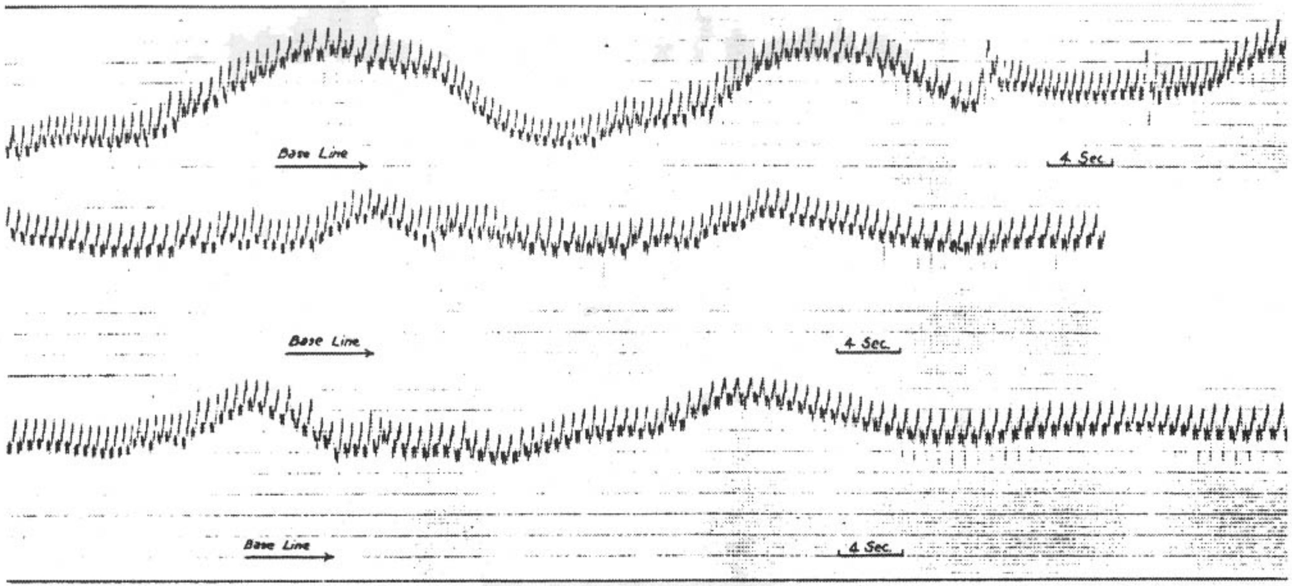

Figure 1.2. Electrocardiogram recorded with limb lead III from an infant with pyloric stenosis. The authors reported that the 20-second wavelike shifts in the tracings corresponded to visible gastric peristaltic waves. Subsequent radiological examination of the child revealed obstruction caused by a pyloric tumor. (Reprinted with permission from Tumpeer and Phillips, 1932.)

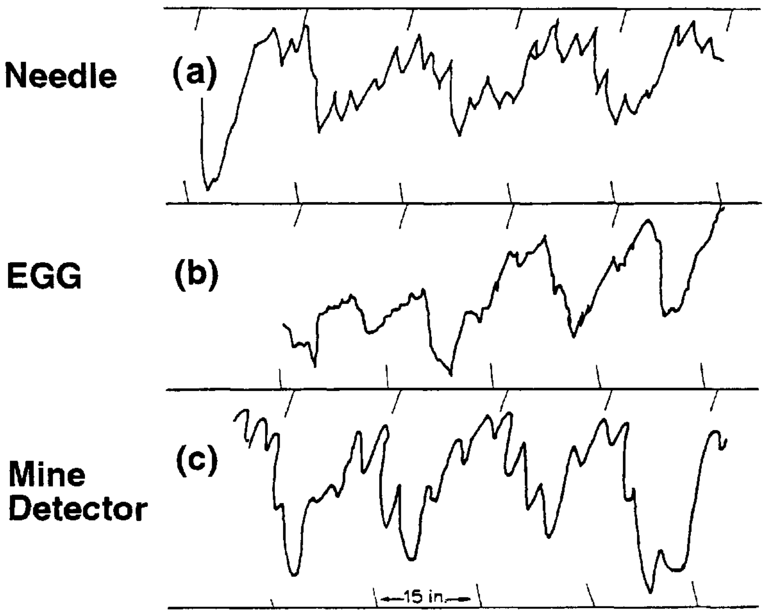

Figure 1.3. Simultaneous recordings from needle electrodes (*a*), electrogastrogram (EGG) (*b*), and mine detector (*c*). The needle electrodes were insulated except at the tip to prevent the recording of galvanic skin responses; one was inserted in the skin of the abdomen and the other in the subject's arm. The EGG electrodes were both placed on the surface of the abdomen. The mine detector tracing was made by having the subject swallow a metal ball and then tracking its movement with a mine detector. Note the similarity in 3-cpm waves in the three records and the baseline shift in the EGG recording. "15 in" indicates 15 seconds. See text for details. (Reprinted with permission from Davis, Garafolo, and Gault, 1957.)

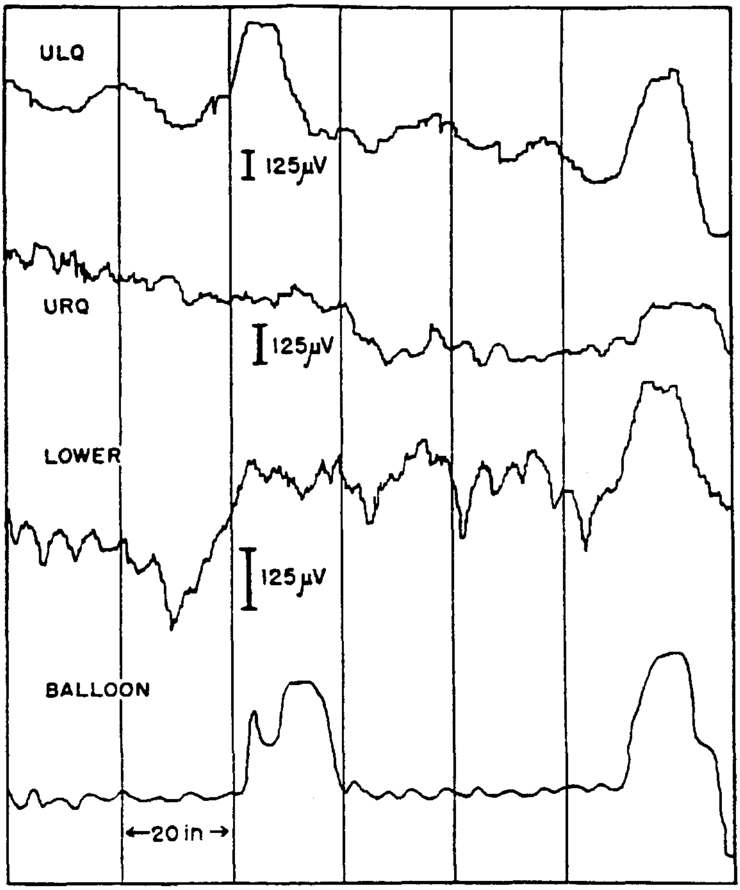

Figure 1.4. Simultaneous electrogastrographic (EGG) recordings from three locations and from an intragastric balloon. The top three tracings are EGGs from the upper left quadrant (ULQ), upper right quadrant (URQ), and lower central location (lower), all referenced to an electrode on the leg. Note that 3-cpm activity is seen more clearly in the EGG recordings than in the balloon recording. The first wave detected by the balloon recording was seen in the ULG and lower EGG recordings. It was not seen in the URQ EGG. Today EGG electrodes are placed in a location that is closer to the antrum. The second large wave detected by the balloon recording was associated with an EGG wave at the three EGG locations. (Reprinted with permission from Davis, Garafolo, and Kveim, 1959.)