Chapter 8
Biomedical Instrumentation

John G. Webster
University of Wisconsin-Madison, USA

ABSTRACT

Biomedical instrumentation is widely used in healthcare to monitor patients, diagnose and treat various pathologies, and advance biomedical engineering research. This chapter covers the measurement of biopotentials for diagnosis, including the electrocardiogram, electroencephalogram, electrocorticogram, electromyogram, electroneurogram, electrogastrogram, action potential, electroretinogram, and electro-oculogram. Pulse oximeters are also covered along with important therapeutic devices such as the artificial cardiac pacemaker, defibrillator, cochlear implant, lithotripsy, ventilator, anesthesia machine, heart-lung machine, infant incubator, electrosurgery, and tissue ablation. The chapter concludes by covering electrical safety, providing future subjects for research such as a blood glucose sensor, and a permanently implanted intracranial pressure sensor, and describing the major organizations that promote the field of Biomedical Instrumentation.

8.1. CHAPTER OBJECTIVES

This chapter covers the measurement of biopotentials for diagnosis: the electrical voltages that can be measured from electrodes placed on the skin or within the body. Biopotentials include: the electrocardiogram (ECG), electroencephalogram (EEG), electrocorticogram (ECoG), electromyogram (EMG), electroneurogram (ENG), electrogastrogram (EGG), action potential (AP), electroretinogram (ERG), electro-oculogram (EOG). This chapter also covers pulse oximeters and important therapeutic devices such as the artificial cardiac pacemaker, defibrillator, cochlear implant, lithotripsy, ventilator, anesthesia machine, heart-lung machine, infant incubator, electrosurgery, and tissue ablation. It concludes by covering electrical safety.

DOI: 10.4018/978-1-4666-0122-2.ch008

8.2. INTRODUCTION

Engineers from electrical engineering, mechanical engineering, and chemical engineering all contribute to advances in biomedical engineering. Almost all biomedical engineers make measurements using instruments, and almost all make therapeutic medical devices. Thus, it is important for biomedical engineers to understand the best way to make measurements in order to select the best instrument for diagnosis. The biomedical engineer also needs to understand what medical devices may be available for therapy or if a new medical device must be designed. This chapter provides an introduction to a variety of successful medical devices and instrumentation.

8.3. DEFINITION OF BIOMEDICAL INSTRUMENTATION

Medical instrumentation is a subdivision of biomedical engineering. It emphasizes the measurement of all the variables in the body for the use of diagnosis and all the devices that perform therapy. Because the bulk of these measurements and therapies involves electronics and computers, the ideal background is in electrical and computer engineering.

8.4. HISTORICAL BACKGROUND AND LITERATURE OVERVIEW

Among the earliest electrical experiments were those by Luigi Galvani. In 1771, he discovered that the muscles of dead frogs' legs twitched when struck by a spark.

Willem Einthoven invented the first practical electrocardiogram (ECG or EKG) in 1903. Einthoven placed the hands and feet of subjects in buckets of saline and used the string galvanometer to record the electrocardiogram (ECG) without electronics. The string galvanometer used a thin filament of conductive wire passing through strong electromagnets. When current passed through the wire, it would move the wire and its shadow from a light, which darkened moving photographic paper, which recorded the ECG.

In 1926, William Bovie developed the electrosurgical unit, which permitted surgery on vascular organs such as the brain, liver, and spleen. The development of the transistor and the computer enabled a flowering of the many advanced diagnostic and therapeutic devices we find in hospitals today.

Principles of Applied Biomedical Instrumentation, 3rd Edition, L.E. Geddes and L.E. Baker, John Wiley & Sons, New York, 1989, covers physiological events, many types of sensors, stimulators, radiant energy devices, ventilators, and anesthesia equipment.

The Encyclopedia of Medical Devices and Instrumentation, 2nd Edition, J.G. Webster, Ed., John Wiley & Sons, Hoboken NJ, 2006, is a six volume work of 300 articles that describes critical aspects of medical devices and instrumentation.

Medical Instrumentation Application and Design, 4th Edition, J.G. Webster Ed., John Wiley & Sons, Hoboken NJ, 2010 is a widely used text that encourages design of the above devices and instrumentation.

8.5. ELECTROCARDIOGRAPHIC AMPLIFIER

The high fat, low roughage diet of the western world promotes development of plaque, which deposits inside arteries and eventually plugs them. This can cause a heart attack, stroke, or kidney failure. When a subject experiences chest pain, the first measurement is to take an electrocardiogram (ECG) to determine damage to the heart. Electrodes are applied to the chest. The best electrodes are formed of silver/silver chloride (Ag/AgCl) because the AgCl salt coating the Ag electrodes is very stable, with the voltage changing little in response to movement or electric current flow.