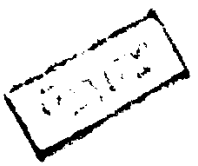
PERMANENT ARTIFICIAL CARDIAC PACING

Analysis of Cases Operated Upon at The Cardiothoracic Surgery Department - Ain Shams University

(June 1975 - June 1980)

THESIS

Submitted in Partial Fulfilment For
The Master Degree of Surgery



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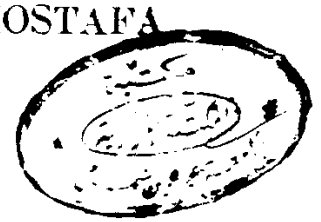

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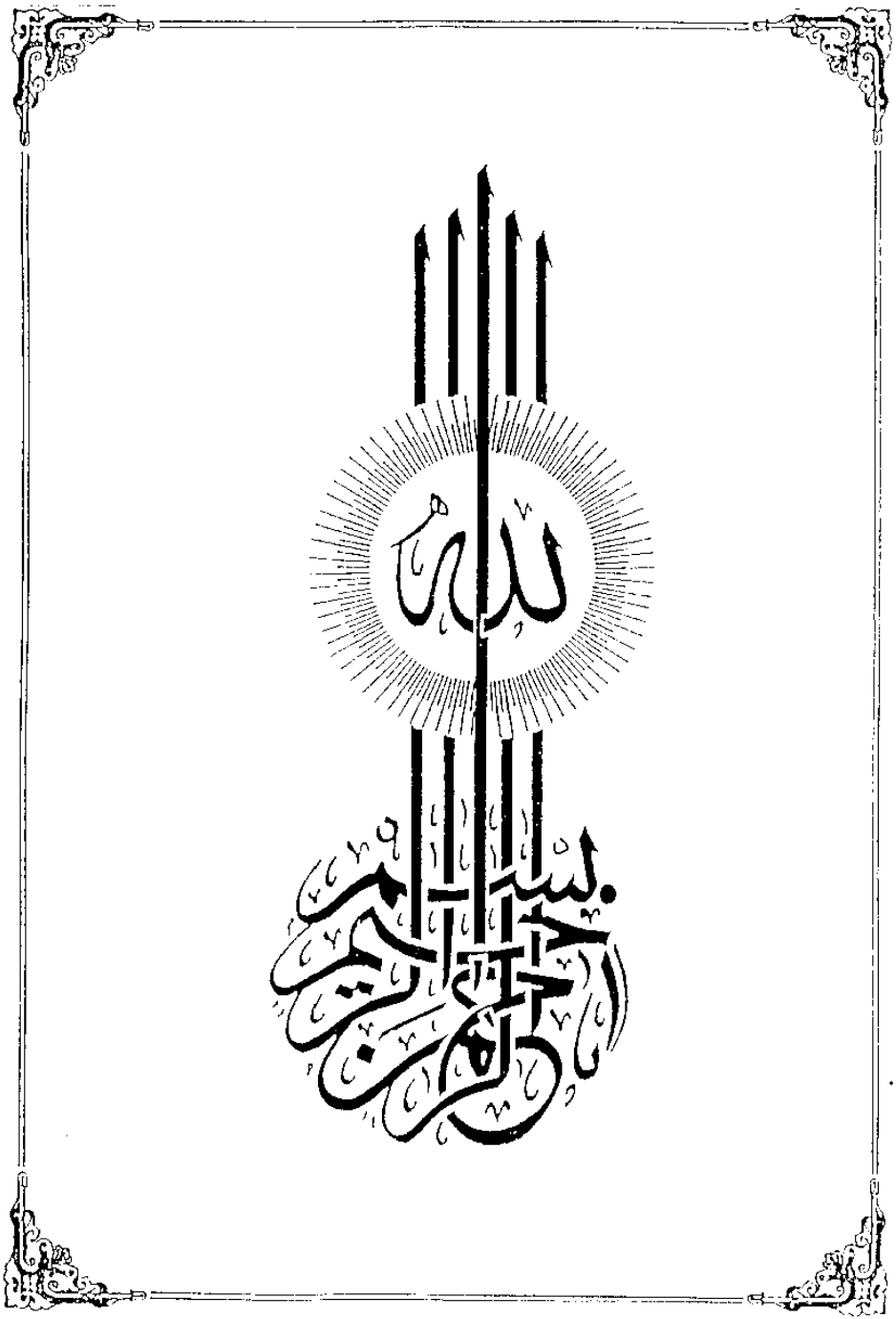
My dear supervisors.

Thank you for all, and for ever.



C O N T E N T S

INTRODUCTION AND REVIEW OF LITERATURE

The pacemakers of today look quite modern... are obviously the product of a very advanced state of technology. So how new is the concept of electrical stimulation of the heart ?

1. EARLY HISTORY (1774 - 1932) :

In the annals of the Royal Human Society, London, there is recorded the case of a child who has fallen downstairs, and whose heart had apparently stopped as a result of the shock. Some sort of current source was brought into the case, and the stimulating pulses were applied to various parts of her body, with no response. The pulses were then applied to her chest, over the heart, and signs of life reappeared-the child was resuscitated. The date of this report 1774 !.

Galvani, the great Italian investigator, working in the 1780's, did many experiments with electrical stimulation of living tissue, including frog's hearts. He reported on the short length of life of the heart muscle following removal from its blood supply.

Vassali and colleagues, working in Turin, Italy, received permission to experiment on the bodies of decapitated criminals immediately after execution. Using Volta's early battery, the "Voltaic pile" he stimulated the heart and produced strong contractions.

Interest in electrical stimulation of all parts of the body grew strong through the mid-1800's. In 1872, a French investigator, Duchenne de Boulagne, developed this portable electrical stimulator, for use in resuscitation and in cases of slow heart rate or cardiac arrest. He reports having successfully stimulated the heart of a diphtheria patient who was suffering from an abnormally slew heart rate (bradycardia).

If any one man should be considered the father of pacing it is. A.S. Hyman. He coined the term artificial pacemaker and was the first to clearly state the principle of pacing : that a small electrical stimulus, applied to a very small area, can give rise to a wave of contraction which will then spread through the entire heart muscle, giving a relatively normal contraction. In co-operation with the Electrophysical Department of New York University Hymen succeded in 1932 in contructing an apparatus for stimulation which used for ambulance use. It was powered by a clock spring. (Wound by a crank) and generated pacing pulses that were fed into the heart through a bipolar electrode needle-this needle would be passed between the ribs of the patient, and into the heart.

THE DEVELOPMENT AFTER 1932 :

Bigelow et al (1950) and Callaghan and Bigelow (1951) described improved electronic pulse generators, endocardiac electrodes, and successfully used transvenous endocardiac stimulation in the experimental animal. The chief interest of these investigators was the area of bradycardia and cardiac arrest during hypothermia.

Early clinical work on pacing was done by Zoll, in 1952. He used skin electrodes on the patient's chest; transmitting enough of a shock to cause the heart within to contract. His work proved the life-saving value of pacing, and sparked intensive investigation in a number of medical centers in the years following.

In 1959, the first cardiac pacemaker was implanted, subcutaneously, by Elmquist and Senning. The electrodes were sutured to the epicardium after the heart had been exposed by a thoracotomy. In Germany, in 1961, Sunder-Plassmann carried out the first pacemaker implantation after thoracotomy. Since this time, a large number of surgical techniques have been developed. As a rule, on account of the reliable fixation of the electrodes to the heart, heart and chest surgeons gave preference to thoracotomy or, later, after further development; to the extra pleural, transmediastinal or transdiaphragmal approach.

Experimentation on pacemakers for implantation began in the 1950's, and the first implants were done around 1960. The Medtronic pacemaker was one of the earliest built. This early pulse generator was developed by Dr. William Chardack, a surgeon, and Wilson Greatbatch, an electrical engineer. It had a circuit that remained basically the same for almost 10 years, was powered by a battery of 10 mercury cells, and set the pattern for most successful implantable pulse generators to come.

The electrode assembly is a very early design, by Dr. Samuel Hunter, a Saint-Paul surgeon, and Norman Roth of Medtronic. This "Hunter-Roth electrode" involved a silicone rubber base plate, bearing two spike electrodes that penetrated the heart muscle, and was used for several early implants. It had inadequate service life, but helped prove the concept of long-term cardiac pacing. It was followed shortly by the spring-coil electrode lead, developed by Dr. Chardack, which dominated the field for many years.

The first clinically practicable external pacemaker was developed by Earl Bakken of Medtronic in early 1958, in cooperation with Drs. W.L. Weirlich and C.W. Lillehei, surgical investigators at the University of Minnesota.

This unit was made small and independent of 110-volt power, by the use of transistors. It made the safe, truly portable pulse gnerator a reality, and encouraged widespread investigation of electrical stimulation for heartblock.

When open-heart surgery began to be conducted in the early 1950's, interest in electrical control of the cardiac rate was soon renewed, because the inadverten induction of temporary or permanent heart block during the repair of intracardiac defects was a fairly frequent and often lethal occurrance during the developmental period of this type of surgery. Treatment of this complication by cardioaccelerating drugs was unsatisfactory except for short periods of time, and its management was dramatically improved by the introduction by Weirich et al (1957) of myocardial electrode wires. These wires, of small diameter, were anchored to the myocardium and brought out through the chest wall at the time of operation. The currents required to pacemake through such wires are ONLY a few milliamperes and well below the threshold of pain.

This approach to the treatment of surgically induced block was very effective. It brought about the development of battery-driven external pacemakers of small size

and of silicone rubber-insulated bipolar stimulation (Hunter et al., 1959). This promptly led to the application of the technique to patients with chronic block (Lillehei et al., 1960). In 1959, Furman and Robinson reported on their first clinical trials with a transvenously placed endocardiac electrode to maintain the heart rate of such patients. It was then realized that long-term electrical stimulation of the heart by electrode structures gaining entrance through the skin had limitations because of the risk of accidental disconnection, infection, and the inconvenience of an externally worn appliance. Two approaches were made to solve the problem of long-term pacemaking without violating the integrity of the skin.

Partially implanted pacemaker systems were introduced in 1959 by Glenn et al, who reported the clinical use of radio-frequency waves transmitted through the intact skin to a receiver implanted in the subcutaneous tissues. From there, the stimulus, appropriately modified by the implanted receiver, was transmitted to the heart by an electrode wire. Similar system described by Abrams et al. (1960) operated by induction coupling between a coil placed on the intact skin and another in

the subcutaneous tissue. Transmission of radio-frequency waves to a small receiver placed directly on the myocardium, eliminating the electrode wires, was reported by Cammilli et al. (1961).

Other investigators pursued the concept of a completely a fully implantable system carrying it's own power supply (Elmquist and Senning, 1959; Chardack et al.,1960; Zoll et al. 1969; Kantrowitz et al., 1962). The first successful long-term clinical use of a self-contained pacemaker operating through myocardial electrodes was reported in 1960 (Chardack et al.) and in the ensuing years implanted pacemaker systems of various types have become the long-term treatment of choice of symptomatic chronic heart block and related disorders.

In the brief span of time since these early reports, new operative technique as well as modifications of older ones have been described, and instrumentation of increasing degrees of sophistication has been developed. Long-term success with a fully implanted pacemaker system operating through a transvenously placed endocardiac electrode was reported by Siddons and Davies (1963). In the same year, Nathan et al. (1963) reported on the clinical use of an implanted synchronous pacemaker programmed from atrial activity, and more recently, Parsonnet

et al. (1966) reported on the first clinical trial of an implanted pulse generator that was programmed by ventricular activity and operated on the demand principle, emitting stimuli only when the beat to beat rate of the heart falls below a present level (for instance, 70 beats per minute PPM).

In recent years there have also been refinements and new applications of temporary pacing techniques not only to the control of chronic block, but also to that of acute atrio-ventricular block in the course of myocardial infarction. The domain of pacing techniques now also includes the temporary and permanent management of certain uncontrollable tachyarrhythmias; the administration of "paired electrical stimuli" - still experimental at the present time-has been used to slow the rate of the heart and to increase its contractile performance. These temporary pacing techniques-either to increase an anadequate rate or to suppress tachyarrhythmias-have become increasingly important tools in the postoperative care of cardiac and other surgical patients.

During the early years of clinical application of pacing techniques, technical problems with the electrodes and power source were predominant. While the former were solved fairly quickly, the development of long-term

lasting batteries remained a rather stubborn obstacle until finally the clinical use of a nuclear energy powered pacemaker was reported in 1970. (Laurens and Piwnica, 1970). Newly developed chemical systems, such as lithium batteries and rechargeable batteries, are now seeing their initial clinical trial and considerable improvements have been made in the construction of the mercury cell and the efficiency of the electronic circuity.

No doubt, the Medtronic sutureless cork-screw electrode, which has been commercially available since 1973, has greatly simplified myocardial implantation and constitutes a really significant advance in the treatment of patients requiring permanent pacing. This electrode, initially used by Hunter and associates, and by Mansour and associates, does not require wide surgical exposure and can be implanted, even under local anaesthesia, by way of a limited subxiphoid or parasternal approach.

The most ambitious attempt at programming was produced in 1972 and allowed the non-invasive programmability of both rate and output with impulse duration varriation as a function of rate. Thanks to CPI (cardiac Pacemakers, Inc.) which paved the way to the digital programmable pacemakers in 1977. (Mosharrafa et al., 1977).

The two decades that has elapsed since the first clinical application of pacing to Arne Larsson on the 8th October, 1958, in Sweden, has seen considerable changes in the relative importance of the respective roles played by the cardiac surgeon and the cardiologist. The first pacemaker systems to be implanted used myocardial electrodes requiring thoracotomy and for this reason were largely in the surgical domain. When transvenously placed electrodes became popular in the mid 1950's, the cardiologist, conversant with cardiac catheterization; began to play an important role, especially in the development of temporary pacing techniques for therapeutic and diagnostic purposes. The field of cardiac pacing is still rapidly changing and crosses the disciplines of surgery, cardiology, and biochemical and electronic engineering, and in the larger medical centers this has led to the development of specialized teams devoting full-time efforts to pacemaker therapy and the follow-up and surveillance of such patients.