
Pacemakers: Past, Present, and Future



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The pacemaker story is inextricably bound to the art of open heart surgery. Its true beginning was inspired by the difficulties encountered in the early attempts to operate upon and correct the pathology of the human heart.

Past

In spite of the “electric” stimulation craze during the eighteenth and nineteenth centuries following the development of the Voltaic pile (battery) and the demonstration of muscle stimulation by electric shock on animals and decapitated criminals, the real beginning of pacing as we know it today began in the middle of this century. Most of the pioneers are not only still alive, but are still busy with the future. Albert Hyman investigated ways of stimulating the heart in the late twenties and early thirties. At that time, drugs were injected into the ventricular cavities (still are, sometimes) in an attempt to restart the heart. Hyman began to observe that the needle rather than the drugs might be the stimulus. He devised an electrical pacemaker which was spring wound and had to be rewound every six minutes. Using electrodes introduced into the heart transthoracically via a needle he was able to keep two patients alive for 24–48 hours. The year was 1932. Hyman continued his work of developing “heartticklers,” but World War II interfered. His units were destroyed by allied bombing of the Siemens factory.

After the war, interest in cardiac surgery quickened. The work of Harken and others with battle casualties opened the door. Despite interest in pump oxygenators, the repair of simple congenital lesions was attempted by Swan and others under general hypothermia. The patient was anesthetized and placed in a bathtub of ice water. The core temperature was reduced to 32° C. This gave the necessarily rapid operator about six safe minutes to close the holes in the atrial septum. One problem still remained. Cold hearts had a tendency to arrhythmia. Bigelow and Callahan attempted to pace the heart in dogs with an electrode in the esophagus and another over the precordium. This work was presented in 1950! Both surgeons are still going strong. Paul Zoll continued his work with external electrodes, developing many basic principles. Work continued on permanent, implantable devices; however, it awaited the development of the transistor and suitable electrodes. Lillihei utilized a suture electrode coincident with open heart surgery. Then Furman developed the endocardial electrode.

Priorities are difficult. Sennig and Elmquist implanted a “permanent” pacemaker in a Mr. Larsson in 1958. It didn’t last very long, however Mr. Larsson did. He was present at the International Pacemaker Symposium in Montreal in October, 1979, wearing his twenty-third pacemaker!

The first truly long term pacemaker was implanted by Chardack, Gage, and Greatbatch in 1960. Great-

batch built the first ten in his barn. The components cost \$2000!

Sennig's unit had to be recharged inductively. Greatbatch's unit utilized mercury-zinc cells that became standard until 1973. This opened the door to many refinements and eventually the pacemakers we have today.

Stephenson described a pacemaker (external) that was triggered by the P wave in 1959. In a comment by Sennig on that paper, he expressed doubts about permanent pacing since the threshold increased so much over time. New electrodes were needed.

Present

These early events spawned a now gigantic industry. There are well over thirty pacemaker manufacturers over the world. At the recent meeting in Montreal, twenty were represented with sales booths.

A pacemaker "system" consists of three elements; the electronic pacing package, the power source, and the lead. ("Lead" includes the connector, the transmission wire, and the electrode tip.)

The electronic packages today are almost cybernetic in function. From the early asynchronous units with a steady beat to today's demand and programmable units has been a matter of only a few years. We now have units that can be programmed not only for rate, but also for pulse width, output, and other parameters. We have gone from electronics that required individually soldered transistors to hybrid packages using CMOS chips of incredibly small size and taking the place of many transistors. These packages are electrically balanced by a computer and have their resistances trimmed by laser beams. We are getting close to "monolithic" circuitry the size of a speck of dust.

Power sources have also changed rapidly. The early mercury cells lasted from 12–36 months. The "ideal" nuclear power sources could last forever (nearly), many are still going. However, the stringencies of government regulation, strict control of the patient, and possible excess radiation exposure have all but eliminated them. This was brought about by the development of the Lithium power source by Greatbatch in 1973. Almost 99% of implanted pacemakers today are Lithium

powered. The Mercury powered units could not be hermetically sealed since they emitted gas. This led to other kinds of problems. Lithium cells are not flatulent and units are now completely sealed. Some Lithium units are warranted for ten years. Since they have not run out their estimated lifetimes, we do not know how long they will actually last.

The lead has been a large problem in the past. From large surface electrodes that built up resistance and required more and more electricity to function, we now have smaller electrodes that require a little more current until they level off in a few months. Indeed we have been pleasantly surprised at the low thresholds of some of the later leads when changing pulse generators recently. Lead breakage has diminished with triple or quadruple wound wires. In short, they are much more reliable today.

Future

Some of the future is with us today. Most of the units implanted today are fairly simple demand pacemakers that rest when the heart beats and pace the heart when it doesn't, given a preset rate. Recently more sophisticated programming became available. Over the past six years, programmability has been simplified (for the user) and is useful for some patients, especially children and perhaps in some patients with so called sick sinus syndrome. Much work has been done with atrial pacing, atrio-ventricular sequential pacing, pacemakers that can overcome several arrhythmias on demand, and even some that can defibrillate the heart from inside (also on demand). The exact indication for this technology is still unclear.

With the development of monolithic and more complicated electronics, more long lasting power sources, and improved lead technology—pacemakers with waveform analysis computers, biochemical sensors, and even therapeutic modes may be possible. Greatbatch has predicted biochemical and gas analysis sensors that will be available to us in the future as well as "biophysical electrochemistry" apparatus useful in tissue healing and infection control.

With Wilson Greatbatch's track record, I wouldn't be a bit surprised.