THE PACEMAKER CLINIC
ELECTRONIC TESTING

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Several different measurements and methods have been advocated for the clinical follow-up of patients with implanted pacemakers. The methods described here are those developed at the Winnipeg General Hospital over the past ten years and those of other investigators which we have tried. These methods were developed in an attempt to evaluate the condition of the pacing system so as to:

(a) Detect and diagnose existing failures of the pacing system,
(b) predict impending failures before they occur,
(c) compare pacemakers and pacing methods.

The measurements consist of:

(1) The measurement of threshold and resistance of the electrodes at the time of implantation and at subsequent rentries. These measurements are used to evaluate the condition of the electrodes and their suitability for further use.

DEFINITIONS:

THRESHOLD: Threshold current is the minimum current required to capture the heart. If the heart has some spontaneous activity this may be difficult to determine but can usually be done by pacing at a rate greater than the spontaneous rate. If a faster rate cannot be used, the criteria for threshold may have to be changed to the ability to elicit a response rather than complete capture.

ELECTRODE RESISTANCE: With a constant current pacemaker, the voltage at the end of the pulse will represent the resistive component of the electrode impedance since the capacitive components will usually be fully charged after 1.5 millisecond. The electrode resistance includes polarization effects at the electrode surface and so is current-dependent. The resistance is usually quite stable for a particular electrode. Resistance measurements are of value in determining breakage of the electrode wires. If the threshold is normal but the resistance is high or variable, this usually means that the electrode is in position but the lead is broken.

R-WAVE AMPLITUDE: The amplitude of the "R-wave" sensed by the electrodes must be sufficient (2-3 mv.) to trigger a standby (or synchronous) type of pacemaker.

(2) Tests on removed pacemakers to define the mode of failure.

(3) Assessment of pacing effectiveness from the ECG and pulse rate measurements. These measurements are made during the visits to the pacemaker clinic at three month intervals and pulse rate is also counted by the patient at home.

(4) Surface measurement of the pacing impulse to detect changes in shape and amplitude indicative of impending failure.

(5) Assessment of battery life by x-ray.

The internal measurements were made using a battery powered constant-current pacemaker and a battery powered oscilloscope to avoid the possibility of electrical shock. The pacemaker has a pulse width of 1.8 ms. and is adjustable over 0.25 - 16 ma. constant current within the limitation of an 18 volt output.

FINDINGS:

(1) Contrary to our expectations, the thresholds are low and stable over many years if an initial "good" position is obtained (one with low threshold).

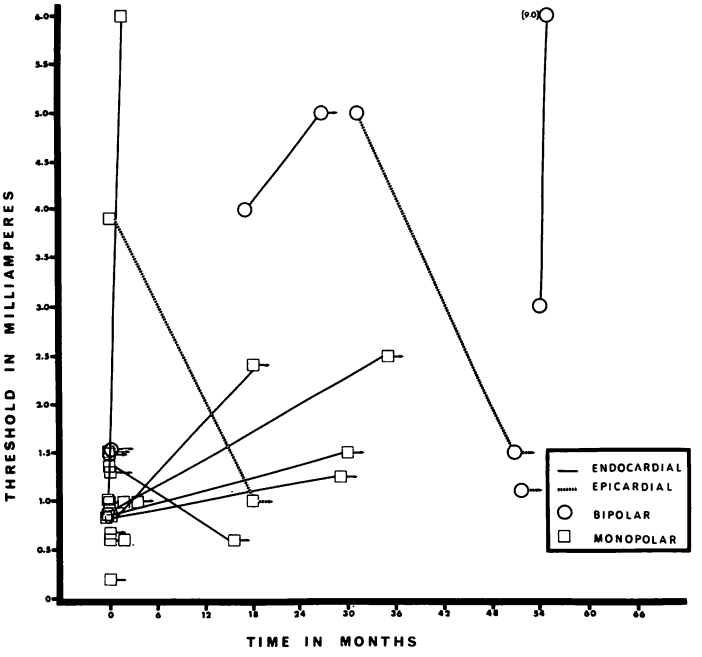
(2) Resistance measurements are very stable and are now only used for the detection of broken leads.

(3) X-ray assessment of battery condition in-vivo is extremely difficult and impractical. X-ray of a removed pacemaker under standard conditions is useful to confirm premature cell depletion.

(4) Changes in the shape of the pacing impulse measured at the surface of the body can be used to detect partial failures of the pacemaker in some types of pacemaker. Usually the change in shape or amplitude is coincident with a change in rate or other manifestation of partial pacemaker failure.

(5) Due to the different and ever-changing modes of pacemaker failure, it is impossible to predict impending failures. The major fault lies with the mercury cells and their unpredictable failure mechanisms when used in the pacemaker environment. Predictions will only be possible when models have been in use long enough to accummulate a failure history; or if the manufacturers build-in operating characteristics that reflect changes in the battery condition.

ELECTRODE THRESHOLD MEASUREMENTS



ELECTRODE RESISTANCE MEASUREMENTS