Factors Influencing Survival of Patients with Permanent Cardiac Pacemakers

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With the advent of permanent cardiac pacing, technology has produced power sources that will last two, four, and even 20 years. The cost of these devices is proportional to their complexity and expected life. Therefore, the selection of an appropriate pulse generator should be based on the patient's prognosis. An actuarial analysis of 319 consecutive patients receiving permanent cardiac pacemakers was performed in order to determine whether prepacing factors influenced prognosis. The survival probability at 5 years was not influenced by sex, race, type of conduction defect, or antecedent disease. Survival rate decreased only slightly for each decade of life, but even in the ninth decade there was an acceptable prognosis.

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THE FIRST clinical application of permanent cardiac pacing was reported in 1961.[1,10] At that time, permanent cardiac pacing offered palliation to those few patients who were diagnosed as having permanent complete atrioventricular conduction block and who could tolerate general anesthesia and a thoracotomy. During the subsequent years, many changes have occurred in the approach to cardiac pacing. These changes have included: 1) an improvement of surgical techniques; 2) the development of more sophisticated pulse generators and electrodes; 3) a broadening of the indications for permanent cardiac pacing; 4) an exponential increase in the number of patients identified as requiring cardiac pacing; and, 5) technological developments that have increased the functional life of pacemakers. As a consequence of these changes, it is now possible to institute permanent pacing in any patient from infancy through the ninth decade of life with a low operative morbidity and mortality. This improved technology has provided pulse generators that will function for 2, 4, 7, or even 20 years. However, the cost and complexity of these devices is directly proportional to their expected life.[5]

Unfortunately, little attention has been paid to the longevity of patients with permanent cardiac pacemakers. Without this knowledge, the surgeon and cardiologist will have little rational basis for the implantation of costly and complex long-life pulse generators. In order to determine the justification for permanent pacing, and to select the proper device, it is necessary to know the expected survival of paced patients.

The probability of survival with permanent cardiac pacing was examined by retrospective analysis of the records of 319 consecutive patients receiving cardiac pacemakers at the University of Virginia Hospital during a 12-year period. Survival was also correlated with those factors existing before pacing.

Materials and Methods

Between February, 1961, and June, 1973, 319 patients received permanent cardiac pacemakers. The clinical course of these patients was followed through August of 1973. The hospital charts, office records, and electrocardiograms were reviewed. Followup data were obtained from clinical notes, referring physicians, and autopsy records. The data were placed on punch cards, tabulated by computer, and edited. The survival probability was determined by a standard actuarial analysis. The sig-

Submitted for publication May 10, 1976.

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nificance of difference at 3 and 5 years was determined by the chi-square method, using a 95% confidence limit.

Some of the factors analyzed in this study, and their definitions, are as follows: *Age*—This was defined as the age of the patient at the time of initiation of permanent cardiac pacing; *Congestive heart failure*—This diagnosis was attributed to any patient with a history of congestive heart failure not temporally related to the onset of the conduction disturbance; *Diabetes mellitus*—This diagnosis was based upon the laboratory documentation of diabetes mellitus during the patient's hospitalization. *Antecedent myocardial infarction*—The diagnosis of a previous myocardial infarction was made historically. The infarctions had occurred a month or more prior to admission for cardiac pacing; *Antecendent cerebrovascular accident*—The diagnosis of a previous cerebrovascular accident was made if there was a history or the physical findings of a localized neurological deficit developing and persisting for 24 hours or more prior to admission.

The equipment employed for permanent cardiac pacing varied with the changes in technology. From 1961 to 1966, all patients had epicardial electrodes implanted through a left thoracotomy under general anesthesia. From 1966 to 1973, 87% of the patients received endocardial electrodes implanted under local anesthesia. In 1966 and 1967 atrial synchronous ventricular pacemakers were used in 8 of the patients. However, from 1967 to 1973, the majority of patients received ventricular inhibited, demand-plus generators.* All of the surviving patients returned for followup 6 weeks after operation. Thereafter they returned at 6-month intervals, at which time a history was obtained and a physical examination, electrocardiogram and fluoroscopy were performed. All patients were asked to return to the hospital for an elective replacement of their pulse generators at the time of the manufacturer's predicted 5% failure rate due to depletion of the power source of the specific device.

Results and Discussion

Entire Group

The 319 patients undergoing permanent cardiac pacing accumulated a total of 10,756 pacing months. The age at the time of initiation of pacing ranged from one year to 97 years, with an average of 68.8 years. Each of the patients was followed either to the time of death or to the completion of the study. The majority were referred from outlying communities. Fifty-three per cent lived 50 miles or more from the Medical Center, and 24% at a distance greater than 150 miles.

TABLE 1. *Causes of Death*

Pulse generator failure	1
Acute myocardial infarction	9
Congestive heart failure	10
Cerebrovascular accident	9
Unrelated causes	14
Unknown	11
Total	54

During the period of study there were 54 deaths (Table 1). The cause of death was determined as follows: pulse generator failure, one patient; acute myocardial infarction, 9 patients; congestive heart failure, 10 patients; cerebrovascular accident, 9 patients; causes unrelated to heart disease or conduction defects, 14 patients; cause of death unknown, 11 patients. Siddons[6] analyzed 145 deaths occurring in patients with permanent cardiac pacemakers. Approximately one-third of the deaths were due to causes unrelated to pacing or cardiac disease, one-third were the result of cardiovascular disease but unrelated to pacing or the underlying conduction defect, and one-third were due to sudden unexplained death, insufficient followup, or to failure of the pacing system. In this study, the distribution of the specific causes of death was similar; however, the cause of death was not necessarily related to the antecedent risk factors.

Ideally, the survival of a paced population should be compared to that of a similar unpaced population. There are several reports of the natural history of patients with Adams-Stokes attacks and/or complete heart block. Johansson[4] found that only 50 per cent of these patients survived one year after the diagnosis was established. Unfortunately, the study was based on patients with complete heart block who were treated before the era of permanent cardiac pacing. In order to evaluate the true effectiveness of cardiac pacing, it would be necessary to randomize similar patients into paced and unpaced categories in a prospective study. The value of permanent cardiac pacing is so well established today that such a randomized study is not ethically possible.

In order to provide a group for comparison, the Virginia State Life Tables for 1959–1961[9] were used to develop a population matched to the 319 paced patients by age, sex and race. The survival rates of this matched population are shown in Fig. 1 as 88% at 3 years and 80% at 5 years. The paced population demonstrates a slightly decreased survival rate of 83% at 3 years and 76% at 5 years. However, if the deaths occurring within the first 6 months are eliminated, there is no significant difference in survival between the general population and those patients with permanent cardiac pacing.

* The eight atrial synchronous pulse generators and electrodes were manufactured by the Cordis Corporation, Miami, Florida. All other pulse generators and electrodes were manufactured by Medtronic, Inc., Minneapolis, Minnesota.

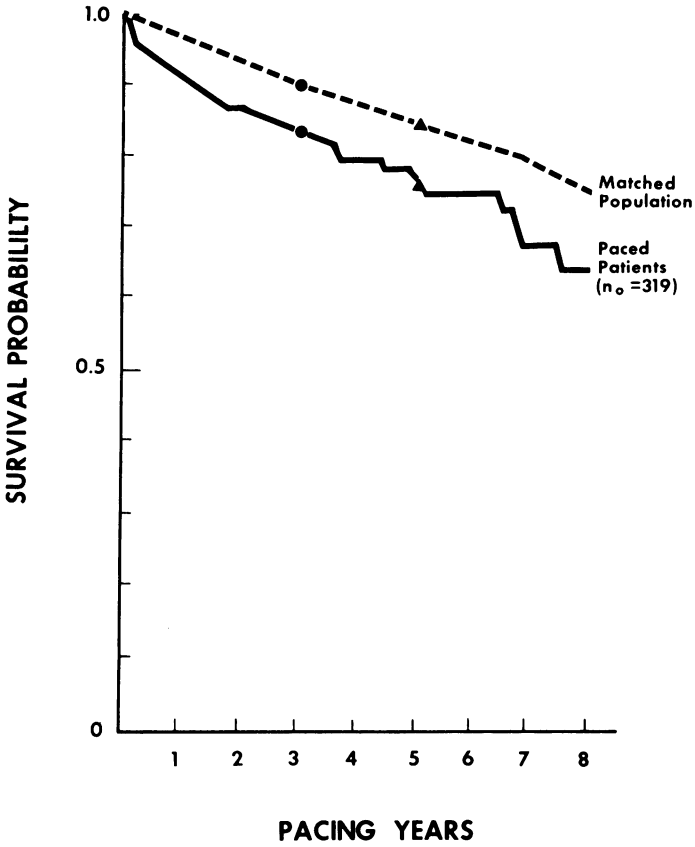

FIG. 1. The actuarial curve of 319 patients with permanent cardiac pacemakers (solid line) compared to a matched population from the State of Virginia (broken line). The 3-year (circle) and 5-year (triangle) intervals are indicated on each curve. If those deaths occurring in the first 6 months with pacing are eliminated, there is no difference between the two groups.

There have been several reports[2,3,6–8] of the survival probability with cardiac pacing, which have indicated a lower survival rate than in this study (Table 2). The reported 5-year survival rate has ranged from 38% to 65%, and the reasons for our improved results are not clear. In two of the reported series,[2,8] the average age of the patients was two to 4 years greater than in ours. On the other hand, it is not possible to determine whether the other antecedent factors were comparable.

TABLE 2. *Survival Probability*

Reference	Number of Paced Patients	Average Age in Years	Survival Probability 3 Yr	Survival Probability 5 Yr
Inberg[3]	49	65.7	63%	38%
Furman[2]	114	72	60%	50%
Van Der Heide[8]	285	70	72%	58%
Siddons[6]	649	68.5	73%	65%
Sowton[7]	161	65.3	80%	65%
U. Va.	319	68.8	83%	76%

Because the patients in this study lived a considerable distance from the Medical Center, it was not possible for the majority to return at frequent intervals to permit detection of impending power source failure. For this reason, a policy was established whereby each patient was readmitted to the hospital for elective replacement of his pulse generator, at the time of the manufacturer's predicted 5% failure rate. It is possible that this method of followup and treatment prevented death due to pulse generator failure.

Sex

There were 188 males and 131 females. The distribution by sex and age is shown in Fig. 2. The 3-year survival probability for males was 83% and for females, 82%. At 5 years it was 75% for both groups. The difference in survival at these two time periods is not significant. For the general population, the survival probability of females is slightly greater than that for males; however, the female requiring permanent cardiac pacing has the same prognosis as the male.

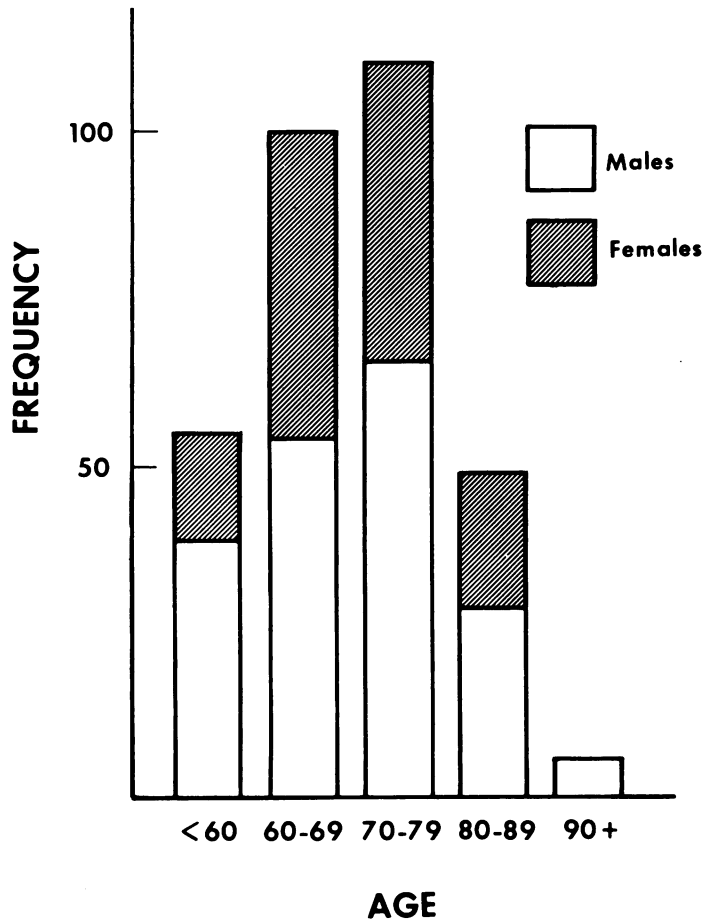

FIG. 2. The distribution of 319 permanently paced patients by age and sex. The age in years is indicated at the bottom of the graph.

Race

There were 281 white patients and 38 non-white patients. Thus, 12% of the paced population was non-white. The non-white population was evenly distributed by age, as shown in Fig. 3. The survival probabilities of the whites were 84% and 77% at 3 and 5 years, respectively. These differences were not significant at 3 years, and at 5 years the number of non-whites was insufficient to permit valid analysis. These findings would suggest that the non-white population has the same prognosis with permanent cardiac pacing as does the white population.

Conduction Disturbance

The presence of atrioventricular conduction block was the justification for permanent cardiac pacing in 217 patients. An additional 63 patients underwent permanent pacing for a sick sinus syndrome. The remainder of the patients were paced for a variety of reasons, including bradytachyarrhythmias, hypersensitive carotid sinus, and

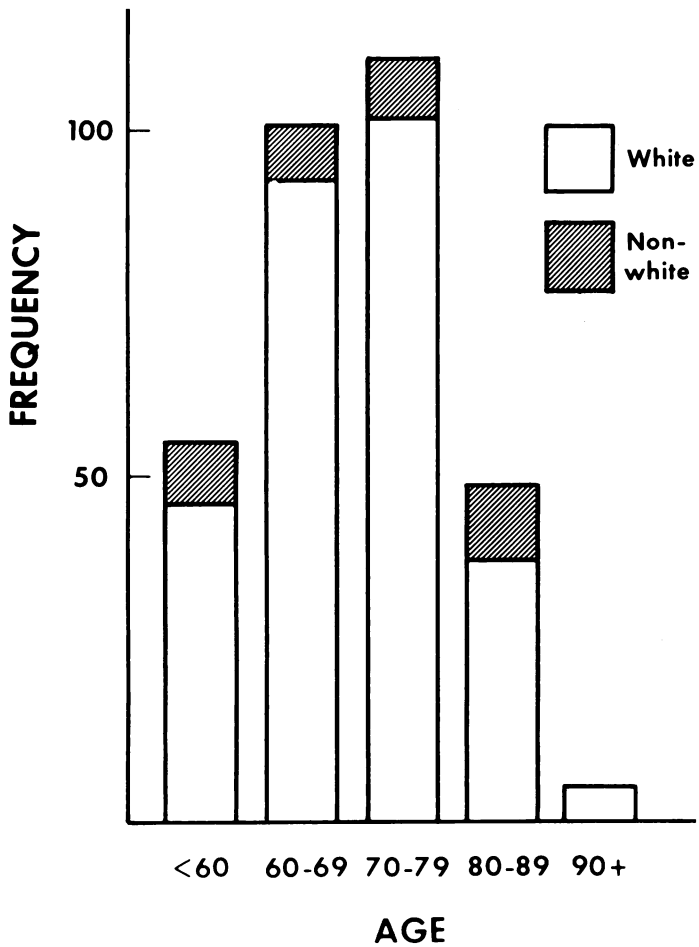

FIG. 3. The distribution of 319 permanently paced patients by age and race. The age in years is indicated at the bottom of the graph.

TABLE 3. *Age vs. Survival*

Age in Years	Number of Paced Patients	Survival Probability	
		3 Yr	5 Yr
<60	53	94%	81%
60–69	100	85%	80%
70–79	111	79%	71%
80–89	49	74%	74%
≧90	6	(67%)*	(67%)*

* Insufficient data

others. The survival probability of the patients with atrioventricular conduction block was compared to that of the patients with sick sinus syndrome. At 3 years the survival rates were 83% and 84%; however, at 5 years, the number of patients with sick sinus syndrome was insufficient to allow valid comparison. That patients with a sick sinus syndrome have the same prognosis as those with atrioventricular block is interesting. Johansson[4] found that, before the pacing era, only 50% of those patients with complete heart block survived for one year. The diagnostic category of sick sinus syndrome is relatively new, and the natural history of this condition is not known.

Age at Initiation of Permanent Pacing

Table 3 lists the number of patients in each age group and the 3- and 5-year probability of survival. There were only 6 patients over the age of 90; this was too small a group for analysis. Figure 4 is a plot of the actuarial curves for each of the age groups through the ninth decade of life. There is a slight decrease in the probability of survival with increasing age. Although 80% of the patients in the seventh decade of life survived for 5 years, only 75% of those in the ninth decade did. All of the patients in the ninth and tenth decade of life were thought by their referring physicians to enjoy a reasonable quality of life, and none was senile. Thus, for patients in the eighties and nineties, permanent cardiac pacing offers a reasonable increase in the length and quality of life.

Antecedent Diseases

In order to develop a group for comparison with patients with antecedent diseases, an actuarial curve was calculated for the "ideal patient." The ideal patient was defined as a white male requiring cardiac pacing but without antecedent diseases. These criteria were met by 101 patients and the survival rate for this group was slightly better than that of a matched general population. When the survival rate of the ideal patients is compared to that of patients with antecedent diseases, the relative prognosis of these conditions can be seen. In Fig.

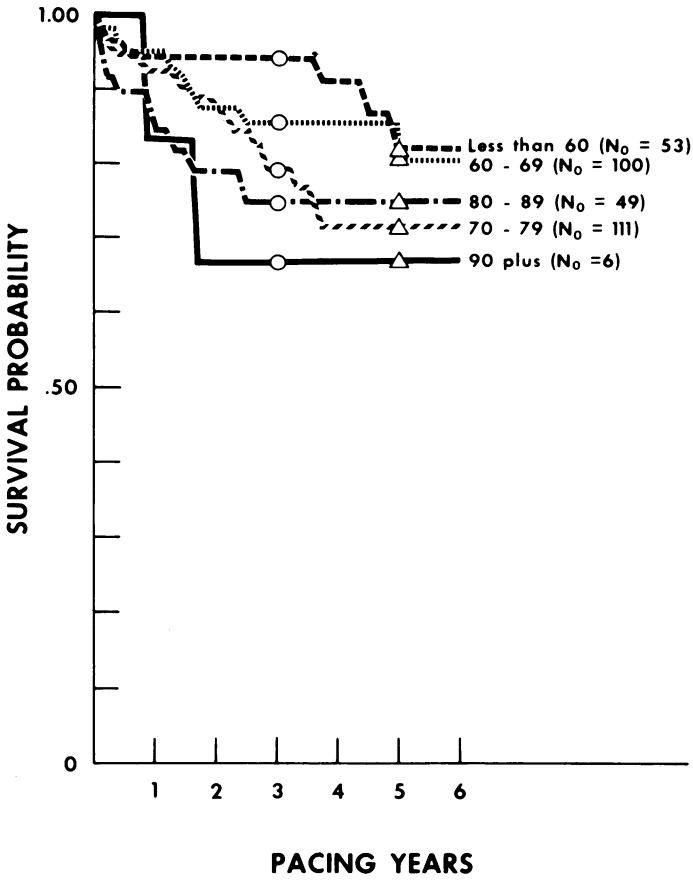

FIG. 4. The actuarial curves of permanently paced patients by age at initiation of pacing. The age range in years of each group is indicated at the end of each curve. N_0 is the total number of patients in each group at time 0. The 3-year (circle) and 5-year (triangle) intervals are indicated on each curve. There were only 6 patients over the age of 90 years. This was too small a group to analyse.

5, the 5-year survival probability for 40 patients with diabetes mellitus was 50%; for 64 patients with congestive heart failure, 70%; for 44 patients with an antecedent myocardial infarction, 85%; and for 21 patients who had suffered a previous cerebrovascular accident, the 5-year survival probability was 59%. These four conditions are usually indicators of generalized vascular disease and, therefore, their existence in patients requiring permanent cardiac pacing has been assumed to carry a poor prognosis; however, only diabetes mellitus or a preceding cerebrovascular accident decreases survival probability, while an antecedent myocardial infarction or congestive heart failure does not change the survival rate significantly.

Conclusions

For this group of permanently paced patients, the survival probability parallels that of the general population. If those deaths occurring within 6 months of the initiation of pacing are eliminated, the survival probability of the paced patients is the same as that of the general population. Several factors have been analyzed which can be determined before the institution of permanent cardiac pacing but which have little influence on the prognosis of these patients. The absolute survival of an individual cannot be predicted from this information, but an approximate prognosis can be established. With this information, it should be possible to determine, before the initiation of permanent pacing, the type of pacing device that should be employed.

Addendum

A paper under this title was delivered before the Southern Surgical Association in December, 1975. Subsequently, a critical error in the preparation of the data for actuarial analysis was discovered, and the manuscript was revised to conform to the corrected analysis. The previous discussion of the paper has been omitted since it is not relevant to the revised text.

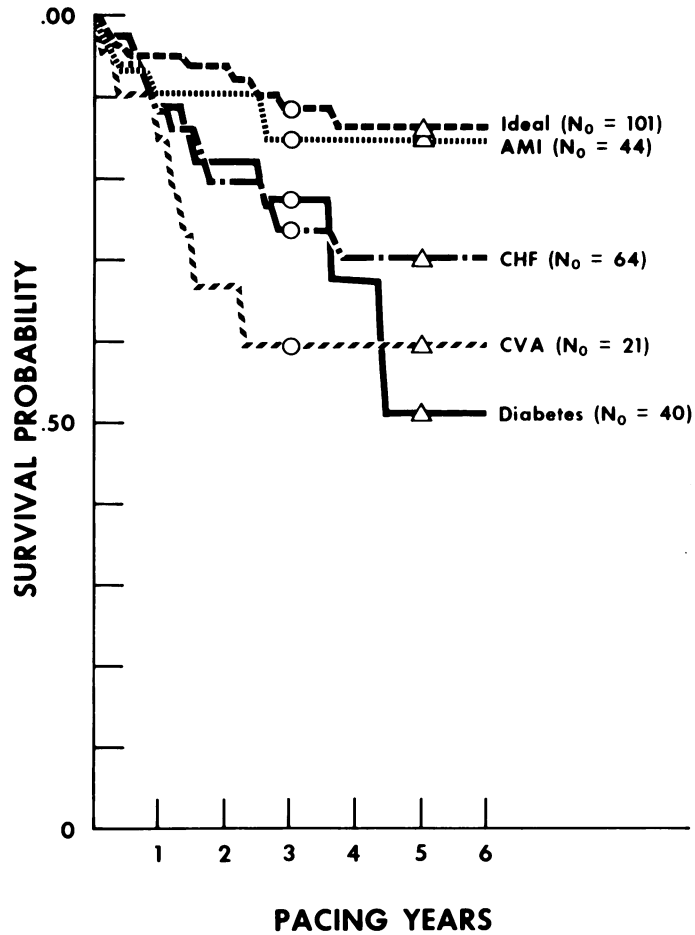

FIG. 5. The actuarial curves for the "ideal patient," and for patients with antecedent diseases. There were 101 "ideal patients," defined as white males without antecedent disease. There were 64 patients with congestive heart failure (CHF), 40 patients with diabetes mellitus, 44 patients with a prior myocardial infarction (AMI), and 21 patients with previous cerebrovascular accidents (CVA). The 3-year (circle) and 5-year (triangle) intervals are indicated on each curve. The pre-existence of diabetes mellitus, or a prior cerebrovascular accident, was associated with a decreased survival probability.

Acknowledgment

We wish to acknowledge the assistance of N. Stephenson and J. Elsberry of Medtronic, Inc., Minneapolis, Minnesota, in the data acquisition for this study.

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