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CARDIAC PACING

The 1981 United States Survey of Cardiac Pacing Practices

VICTOR PARSONNET, MD, FACC, CANDICE C. CRAWFORD, MA, ALAN D. BERNSTEIN, EngScD

Newark, New Jersey

A survey of physicians implanting pacemakers was conducted to obtain a profile of permanent cardiac pacing practices in the United States during 1981. Questionnaires were mailed to 5,832 implanters with 765 responses (13%) received and 680 analyzed. It was estimated that there were approximately 5,600 physicians, 66% surgeons and 34% nonsurgeons, implanting pacemakers at 3,670 centers. About 118,000 new primary implants were performed, or 518 per million population. Only 17% of implantation procedures in 1981 were replacements compared with 31% in 1978. Roughly half the respondents worked in teams, most implanting from 46 to 55 pacemakers annually.

The chief indications for permanent pacing were sick sinus syndrome (48%) and impairment of conduction in the atrioventricular node and His-Purkinje system (42%). Ninety-five percent of pacing leads were implanted transvenously. Seventy percent of the respondents had had experience with atrial and dual-chamber pacemakers, used largely to increase cardiac output. The use of ventricular demand (VVI) pacing decreased accordingly from 91% in 1975 to 84% in 1981. Although approximately 90% of primary pacemakers were programmable to some degree, almost half were not reprogrammed within the first 3 months after implantation and 30% were never reprogrammed. Most patients (85%) were followed up by transtelephonic electrocardiographic monitoring, 68% in conjunction with private office visits. The respondents estimated that dual-chamber pacing, accounting for 10% of implants in 1981, would increase to 37% by 1985.

Early electrode malfunctions were less frequent when implantation was performed by high volume and solo implanters, and in public and community hospitals. It is concluded that periodic surveys of this type disclose important trends in the practice of cardiac pacing.

Since 1969, the results of a series of worldwide surveys of cardiac pacing practices have been reported at the triennial (now quadrennial) World Symposium on Cardiac Pacing. The world was divided into geographic pacing regions, including western Europe, the Far East, Africa, South America and the United States and Canada. The senior author has been responsible for the United States portion of the surveys since the first survey.

Earlier surveys have disclosed numerous trends in pacing. Until now, the most important of these have been related to the total number of primary pacemaker implants and replacements and the gradual changes in indications for pacing and implantation techniques. In 1978, pacemakers were implanted in the United States at a rate of 309 per million population; transvenous implantations were used by 95% of the responding physicians, and ventricular demand (VVI) pacing was the pacing mode chosen in almost every case. Such information has proven useful to physicians, pacemaker manufacturers and third party insurance carriers, who have begun to scrutinize the impact of new developments in pacing on the health care dollar.

The results of the present survey were obtained from responses to a questionnaire distributed in 1982 to pacemaker implanters that requested data from the preceding 12 month period (1981). Data are now available on pacing practices for the years 1969, 1972, 1975, 1978 and 1981, not only for the United States but for much of the world (1–6). In addition to frequencies and percents, this survey included a first attempt at gathering some evidence concerning the quality of work performed and attitudes toward noninvasive pacemaker programming and use of more complex dual-chamber pacemakers.

Methods

Sampling mailing lists. Sampling for this survey presented a special problem in that there exists no complete list of physicians implanting pacemakers. Therefore, a two-stage sampling design was employed to obtain a sample of

From the Department of Surgery and Pacemaker Center, Newark Beth Israel Medical Center, Newark, New Jersey. This study was supported in part by Medtronic, Inc., Minneapolis, Minnesota. Manuscript received October 31, 1983, accepted December 15, 1983.

Address for reprints: Victor Parsonnet, MD, Director, Department of Surgery, Newark Beth Israel Medical Center, 201 Lyons Avenue, Newark, New Jersey 07112.

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physicians that would approximate the larger pacing community.

The American Hospital Association provided mailing labels for every hospital in the country. Four groups of hospitals were classified: those within or outside a Standard Metropolitan Statistical Area (SMSA) (7,8) and those with or without more than 100 beds. Because it was assumed that pacemakers would probably be implanted at most large urban hospitals (more than 100 beds and within an SMSA), each hospital in this group was asked to provide the names of all physicians implanting pacemakers at that institution. An additional 457 hospitals from the other three groups were randomly selected for inclusion. These included hospitals with fewer than 100 beds within an SMSA and hospitals outside an SMSA with and without at least 100 beds. The entire sample consisted of 3,210 hospitals.

As in our previous surveys, pacemaker manufacturers were asked to provide their physician mailing lists; all but one complied. Names obtained from these lists were combined with those provided by the hospitals.

Questionnaire. The main body of the 11 page questionnaire was designed to elicit 1981 (and some 1979 and 1980) data on caseload, indications for pacing, epidemiology, operative techniques, pacing modes, programming and follow-up techniques, along with selected projections for 1985. Five supplementary questions were included regarding pacemaker reuse, rhythm disturbances, electrocardiographic indications for pacing, the potential usefulness of an automatic implantable defibrillator and the incidence of neoplasm observed in tissue in contact with an implanted pulse generator or lead. Although many questions were included because of our own research interests, others were included at the request of the organizers of the World Survey on Cardiac Pacing (6).

The United States Survey on Cardiac Pacing was sent initially to 7,000 physicians. It was mailed to the entire physician population, that is, to each physician on the list, whether an implanter or a referring physician (the manufacturers' lists made no such distinction). A postcard reminder was sent to each nonrespondent approximately 6 weeks after the initial mailing. In addition, a special short form of the questionnaire containing a subset of the original questions was prepared to simplify the collection of data from "important" but reluctant respondents. Because we were especially interested in New Jersey physicians, 180 abridged "New Jersey Surveys" were mailed to these physicians in addition to the main survey. Finally, all New Jersey nonrespondents were contacted by telephone, and some additional data were obtained.

Data analysis. Data analysis consisted primarily of calculated marginal percents and percents for various subsets of physicians (for example, surgeons and nonsurgeons). In addition, chi-square tests of association were performed to find statistically significant differences among subsets of physicians. TACTICS, a statistical package available through COMSHARE, a computer time-sharing service, was used for all data analysis.

Because of the length and complexity of the survey instrument, there were many missing data points. Some of the data were not available and some were difficult for respondents to provide without an extensive review of patient records. Although physicians were asked to provide information relative to their own pacing practices *only*, many responded for a group of implanters at their particular institution or for an entire group practice. This made it impossible to adhere to the original design, which had specified the individual as the unit of analysis. Thus, in some instances, an entire group had to be "counted" as an individual physician. Because it was often impossible to identify which questionnaires represented a single individual's practice and which represented groups of physicians, there was no way to exclude group responses.

Results

Response rates. The response rate from hospitals was 35%. Of the 3,210 letters sent, 285 (9%) were returned marked "pacemakers are not implanted at this institution." Almost a third of the hospitals provided us with the names of staff physicians who implanted pacemakers.* From postcard returns, we were able to estimate roughly the number of hospitals in which pacemakers were implanted. Our estimate of 3,676 "implanting hospitals" is consistent with manufacturers' estimates of 2,200 to 4,000.

Questionnaires were ultimately mailed to 7,000 physicians. Two hundred sixteen questionnaires were returned by the post office as undeliverable, and 952 physicians (13.1% of the total sample) returned the survey stating that they did not implant pacemakers. With these two groups excluded, 5,832 presumably valid names and addresses remained. Four hundred ninety-five physicians (more than 8% of the remaining sample) declined to participate; 765 (13%) of the surveys were completed and returned. Eighty-five responses were received too late to be included in the computer analysis.

Demographics. We estimate that in 1981 there were approximately 5,600 physicians implanting pacemakers at 3,670 centers in the United States. Sixty-six percent of

*Some hospital boards and associations, evidently deluged with survey requests, have developed an interesting method of dealing with such requests. We received many letters stating that the local hospital association required that we complete their questionnaire. The letter stated that if we would complete and return the questionnaire, our request would be placed on the association's agenda and reviewed at its next meeting. If approved, the particular hospital would be happy to complete our "survey." The irony is that many of their "counter-questionnaires" were five or six pages long! All we had asked was that a postcard be returned listing the name and address of the hospital, whether or not pacemakers were implanted there and, if so, who implanted them.

physicians implanting pacemakers were surgeons (mostly general and thoracic) and 34% were nonsurgeons (mostly cardiologists). The respondents had been in practice for a mean of 13.3 years, and were implanting pacemakers for a mean of 11.0 years. The majority (53%) were in private practice or with a single specialty group (24%). Twenty-three percent taught either full- or part-time, but only 3% were engaged in research.

The "typical" pacemaker implanter worked at two hospitals, primarily relatively large (median bed size 379), private (36%) and community (44%) hospitals, and worked as part of a team of physicians (the mean size of the "implant team" was 1.6 physicians) approximately half the time (this was a bimodal distribution: 39% "never" and 39% "always" worked in a team). The typical physician had implanted a mean of 327 pacemakers during his or her medical career, and had implanted 37 to 40 primary and 9 to 11 replacement pacemakers during 1981.

We arbitrarily defined a "busy" implanter as one who implanted 30 or more pacemakers a year. Typically, the individual was in a private practice that was not hospital-based. Such a physician was likely to use dual-chamber and atrial pacemakers and multiprogrammable pacemakers, favor the reuse of pacemakers and reject the assistance of a manufacturer's sales representative at the operating table.

Growth of pacing (Fig. 1). Most centers began pacemaker implantation during 1969, yet 75% did not have a special pacemaker department or service, and only 54% had "specific written guidelines governing surgical privileges for pacemaker implantation." The yearly number of new pacemaker implants grew from 66,724 in 1978 to 117,800 in 1981, increasing from 309 to 518 new implants per million population. Replacement units decreased markedly, from 31% of the total implants in 1978 to 17% in 1981.

Indications for pacing (Fig. 2). Sick sinus syndrome, which accounted for 23% of indications in 1975, increased to 48% in 1981. The respondents did not expect this increase to continue, estimating that sick sinus syndrome would account for 45% of pacing indications in 1985. Decremental atrioventricular (AV) conduction at the level of the AV node and His-Purkinje system as an indication for pacing decreased steadily from 59% in 1975 to 42% in 1981. A further decrease to 35% was anticipated by 1985.

Pacemaker implantation for the treatment of tachyarrhythmias was expected to increase only slightly, from 1.9% in 1981 to 3.9% by 1985. The largest increase in indications, however, was expected in the category of "other" indications (8 to 16%). It is unclear what the respondents meant by "other."

Pacing technique. Ninety-five percent of pacemaker leads were implanted transvenously. The standard cut-down technique was used in 73% of cases, and an introducer was used at times by 50% of the respondents. The procedures were performed in the operating room in 58% of cases, the catheterization laboratory in 24%, the X-ray department in 14% and a special procedures room or "other" facility in 5%.

Sutures were used to affix pulse generators to the surrounding tissue in 42% of cases, and a cloth cover was employed in 6%. (Comparable 1978 figures were 34 and 9%, respectively.) Thus, pulse generators were affixed to the surrounding tissue in some way in about 50% of cases, an increase from the 37% reported for 1978.

Pacing modes and leads. Figure 3 shows the change in the use of dual-chamber (DVI, DDD and VDD) and single-

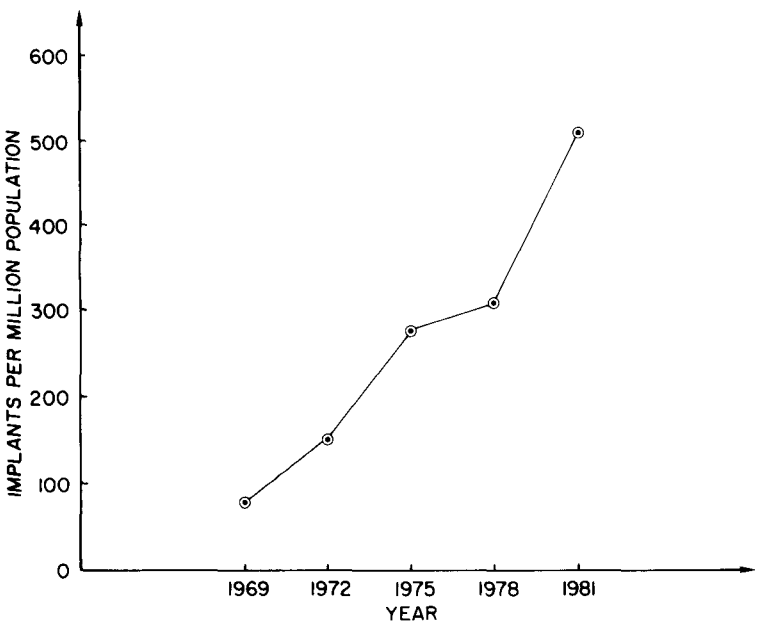

Figure 1. The trend in implantation rate during the 13 year period from 1969 to 1981, showing an increase of roughly 38 implants per million population each year.

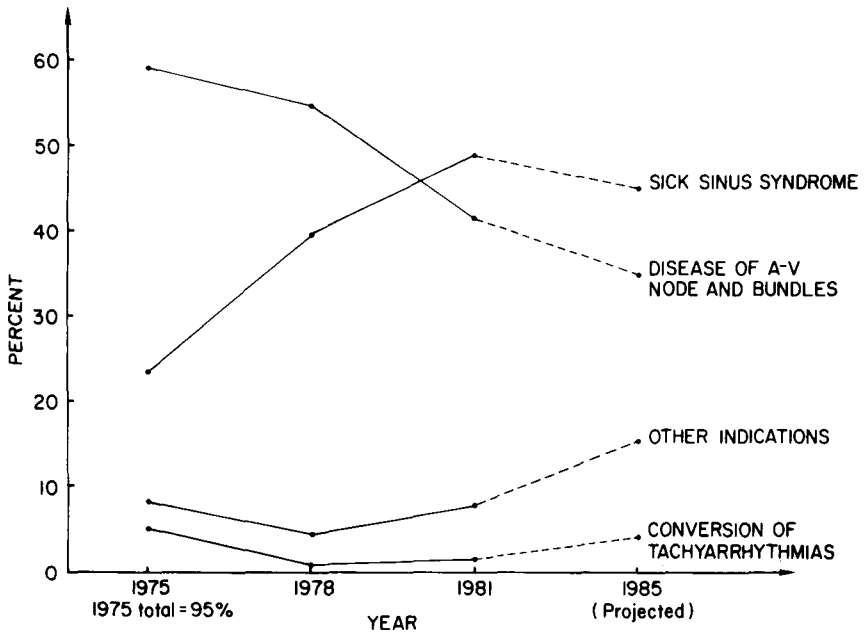

Figure 2. Relative frequency of indications for permanent cardiac pacing during the 10 year period from 1975 to 1985. A-V = atrioventricular.

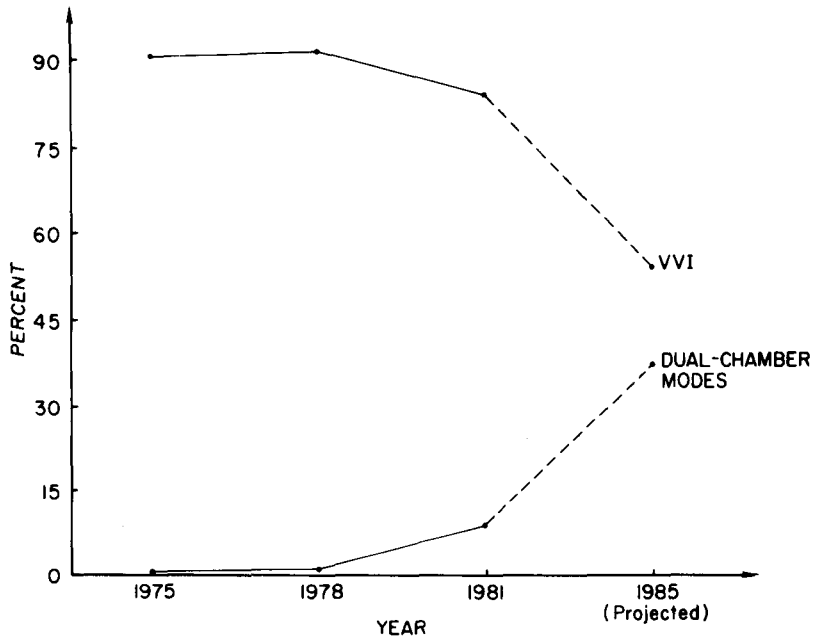

Figure 3. Relative frequency of pacing modes selected for primary pacemaker implants during the 10 year period from 1975 to 1985.

chamber (VVI) pacemakers* from 1975 to 1981, together with projections for 1985. Single-chamber pacemaker usage decreased from 91% in 1975 to 84% in 1981 and is expected to decrease even further to 54% by 1985. The use of dual-chamber pacemakers increased from 0.2% in 1975 to 9.4% in 1981. The prediction for 1985 was 37%. Thirty percent of the respondents did *not* use atrial or dual-chamber systems, either because such a system had not been requested by the referring physician or because the implanter did not have enough experience to use them. Twenty percent believed that there was little need for dual-chamber and atrial pacing. The 70% who reported using atrial and dual-chamber systems chose them primarily to increase cardiac output.

*VVI and other symbolic representations of pacing modes used in this report are taken from a code introduced in 1974 by the Inter-Society Commission for Heart Disease Resources (9). VDD is a pacing mode in which spontaneous atrial depolarizations are sensed and the ventricle is paced after a suitable AV interval (atrial synchrony). This mode provides variable rate ventricular pacing consistent with physiologic need. A VDD pacemaker has the additional advantage of sensing ventricular depolarizations, so that premature spontaneous ventricular beats will inhibit the next pacemaker output (demand function). In the DVI pacing mode, both chambers are paced in sequence, but spontaneous atrial events are not sensed. In other words, it is nonadaptive dual-chamber demand pacing with the ventricle stimulated at a fixed rate unless the pacemaker is inhibited by spontaneous ventricular activity. DDD is the most sophisticated pacing mode, providing the AV stimulation sequence of dual-chamber pacing, the rate adaptivity of atrial synchrony and the demand features of atrial and ventricular inhibition.

Although these systems are reported to have other clinical benefits, the respondents did not consider those to be of equal importance.

Lead preference has shown no consistent pattern since 1975, although unipolar leads have been preferred by most physicians for many years. Half of the respondents expressed a preference for unipolar leads in 1975, and three-quarters did so in 1978. By 1981, however, the preference for unipolar leads had decreased to 62%, and a further decrease to 54% was anticipated by 1985.

Programmability. The use of programmable pacemakers has been steadily increasing. In 1978, 39% of the survey respondents used programmable pacemakers. By 1981, 90% of the implanting physicians used either simple programmable (16%) or multiprogrammable (74%) pacemakers. Almost 10% of the primary pacemakers implanted during 1981 were, however, nonprogrammable, but few respondents (n = 11) explained this preference. Those who provided an explanation felt that a nonprogrammable VVI pacemaker was adequate.

Almost half (47%) of the programmable pacemakers implanted were not reprogrammed within the first 3 months after implantation; 35% were not reprogrammed within the first 12 months and 30% were never reprogrammed. Nevertheless, most respondents believed that multiprogrammable pacemakers were "clinically important," especially for young patients (Table 1). Multiprogrammability was considered useful, primarily for troubleshooting pacemaker problems as ranked by respondents on a 4 point scale (1 = very useful, 4 = not useful). An average usefulness score of 1.7 was assigned to troubleshooting, followed closely by adjustment for physiologic needs, which was scored 1.8. Multiprogrammability was considered least useful for "fine tuning" after implantation, receiving a score of 2.4.

The management of pacemaker programming is summarized in Table 2. Pacemakers were most frequently programmed immediately after implantation (29%) and when there was an apparent problem (38%). Programming was performed in the physician's office and in a hospital facility (other than a pacemaker clinic) at almost the same rate (26 and 29%, respectively). Pacemaker clinics were used less frequently (18%). Pacemaker programming was performed by the implanting physician in 51% of cases and by a follow-up physician in 23%. Referring physicians, nurses, pacemaker technicians and manufacturers' sales representatives combined performed 14% of pacemaker programming procedures.

Table 1. Respondents' Assessment of Clinical Importance of Multiprogrammable Pacers in Relation to Patient Age, 1981 (n = 533 to 579*)

Patient Age (yr)	Important (%)	Moderately Important (%)	Slightly Important (%)	Unimportant (%)
≤20	84	11	3	2
21 to 50	75	18	5	1
51 to 70	48	37	14	2
≥71	37	29	27	7

*Numbers vary because not all respondents answered the same set of questions; omissions varied from respondent to respondent.

Table 2. Management of Pacemaker Programming, 1981

	(%)
When performed	
Immediately after implantation	29
Routinely at a fixed date	21
Troubleshooting	38
Other	1
Where performed	
Physician's office	26
Pacemaker clinic	18
Other hospital facility	29
Elsewhere	4
Performed by	
Implanting physician	51
Follow-up physician	23
Referring physician	4
Nurse or pacemaker technician	8
Sales representative	2

Follow-up. Sixty percent of the respondents followed up fewer than 100 patients in their own practice. About the same number of patients were followed up in hospital pacemaker clinics (in 60% of hospitals there was no pacemaker clinic), but of the 40% whose patients were followed up in such a clinic, 50% reported following up 100 or fewer patients in this manner. An additional 20% followed up 101 to 200 patients; only 1% followed up more than 1,000 patients.

Transtelephonic electrocardiographic monitoring was used as part of the follow-up procedure by nearly every survey respondent during 1981, only slightly more than in 1978 (85 and 81%, respectively). Of the 15% who did not use this technique, clinic follow-up was preferred by 47%. Of the nonusers, 26% believed it to be unnecessary and 23% considered it too costly.

The percent of patients being monitored by telephone increased from 51% in 1978 to 60% in 1981. Telephone follow-up was most commonly used in conjunction with private office visits (68%), with clinic visits (30%) and in special circumstances such as infirmity and distance (31%). These figures are almost identical to those in the 1978 reports. Twenty-two percent used transtelephonic electrocardiographic monitors for arrhythmia monitoring and 8% used it exclusively. Most patients (29%) were provided with monitors that transmitted the electrocardiographic signal and the stimulus duration. Monitors that transmitted the electrocardiographic signal alone were used by 28% of patients; rate-only transmitters were used by 3%.

The number of follow-up contacts has increased since 1978 (Table 3). The increasing frequency of follow-up was most apparent in the first year after implantation, particularly

Table 3. Follow-up Contacts; First 5 Years After Implantation

Year Postimplant	Office Visits			Clinic Visits			Transtelephone Monitoring			
	1978	1981	Contact Change	1978	1981	Contact Change	1978	1981*	1981†	Contact Change
1	3.3	4.9	+1.6	2.7	4.1	+2.8	5.9	7.7	8.3	+10.1
2	2.7	3.3	+0.6	2.4	2.8	+0.4	7.4	7.4	9.0	+9.0
3	2.9	3.3	+0.4	3.0	2.8	−0.2	13.0	7.8	8.8	+3.6
4	3.0	3.4	+0.4	2.9	3.0	+0.1	17.6	9.1	10.0	+1.5
5	3.4	4.0	+0.6	3.1	3.5	+0.4	19.4	9.7	11.9	+2.2

*Hospital or office-based telephone service; †proprietary service.

in the use of transtelephonic electrocardiographic monitoring. If the two telephonic monitoring categories specified in the 1981 survey are treated as subsets of the more general category used in the 1978 survey, then the greatest change reflected in Table 3 is in the frequency of telephone contacts.

Pacemaker choice (Table 4). Half of the respondents reported that the manufacturer had a "great influence" on their choice of pacemaker, but more than half said that factors other than those listed in the questionnaire exerted "great influence" over their choice. In descending order of importance were the sales representative, warranty and peer recommendation. When asked to rank the areas of usefulness of the manufacturer's sales representative, the respondents listed their choices in the following descending order: new product information, pacemaker education and technical advice, assistance in programming and assistance at the operating table. The sales representative was considered *least* useful in follow-up.

Pacemaker reutilization. The great majority of respondents favored the reutilization of pacemakers, with 82% believing that lithium pacemakers should sometimes be reused. Refurbishing and resterilization by the manufacturer were preferred by 74%; however, an additional 17% thought that resterilization either by the manufacturer or in-house was acceptable. In fact, 60 respondents indicated that they have resterilized and reused an average of 12.5 pacemakers (a total of 750), and 32 respondents have made an average of 9.2 pacemakers (a total of 295) available for use by others.

Implant volume. Evidence was sought to show differences in practice patterns in various subsets of physicians, such as surgeons versus nonsurgeons and teams versus solo implanters. In general, surgeons tended to be busier (in terms of the number of procedures they performed) than nonsurgeons during 1980 and 1981. Using 50 or more implants as an index, 23 and 19% of surgeons and nonsurgeons, respectively, implanted more than 50 pacemakers during 1980, compared with 20 and 16%, respectively, during 1981 (chi-square [χ^2] = 15.05, p = 0.005 for the 1981 data).

Solo practitioners versus team members. Similarly, solo practitioners implanted more pacemakers than did teams. These figures, too, were significant (p = 0.002 for both 1980 and 1981 data). Nonsurgeons worked most frequently in teams of two or more physicians; 67% of nonsurgeons and 47% of surgeons worked in teams (χ^2 = 20.85, p = 0.001). Moreover, implantation teams were most common in medical schools and private hospitals. Eighty-one percent of physicians working in medical schools implanted pacemakers as part of a team, compared with 52% of those not working in medical school facilities (χ^2 = 13.94, p = 0.001). Sixty percent of private hospital physicians implanted pacemakers as part of a team, whereas 44% of those not working in a private hospital worked in teams (χ^2 = 16.65, p = 0.001).

Nonprogrammable versus programmable pacemakers. "Heavy" implanters (defined arbitrarily as those implanting more than 30 pacemakers per year) used more multiprogrammable pacemakers than did "light" implanters (those implanting fewer than 31 pacemakers per year). Seventy-seven percent of the former used multiprogrammable pacemakers in more than 50% of their cases, compared with 65% of the latter (p = 0.001). Similarly, solo implanters used more multiprogrammable pacemakers than did implantation teams (74 and 65%, respectively; p = 0.046).

For surgeons, the use of both nonprogrammable and multiprogrammable pacemakers was significantly related to implant volume. These relations were not statistically significant for nonsurgeons. Surgeons with a low volume of pacemaker implantations implanted more nonprogrammable (12% implanted more than 50%, compared with 9% for physicians implanting a high volume of pacemakers) and

Table 4. Factors Influencing Pacemaker Choice, 1981

	Great or Some Influence (%)	Little or No Influence (%)
Manufacturer	89	10
Sales representative	74	25
Warranty	70	28
Other factors	70	17
Price	64	35
Peer recommendation	56	43

fewer multiprogrammable (63% surgeons implanted more than 50% with a low volume, compared with 76% for physicians with a high volume) pacemakers than did surgeons with a high volume. The relation between volume and percent of nonprogrammable pacemakers yielded a chi-square value of 8.82 ($p = 0.032$); between volume and percent multiprogrammable pacemakers, the chi-square value equaled 8.12 ($p = 0.002$).

For low volume implanters, a statistically significant relation was found between percent nonprogrammable pacemakers implanted and the number of physicians on the implant team ($\chi^2 = 8.12$, $p = 0.044$) and between percent simple programmable pacemakers implanted and the number on the implant team ($\chi^2 = 7.86$, $p = 0.049$). For this group, solo physicians implanted a higher percent of nonprogrammable pacemakers (12% implanted more than 50% nonprogrammable pacemakers) than their team counterparts (8% of whom implanted more than 50% nonprogrammable pacemakers). Low volume team implanters, however, used a higher percent of simple programmable pacemakers. Nineteen percent of solo physicians and 24% of team physicians implanted more than 50% simple programmable pacemakers in 1981.

Pacing mode. The use of DVI pacemakers was related to the number of years of physician practice. Physicians who had been in practice for more than 10 years used more DVI pacers in 1981 than did those who had been in practice 10 years or less. Of the respondents in practice for more than 10 years, 8% had used DVI pacemakers in more than 50% of implantations, compared with only 4% of physicians in practice for 10 years or less. This relation approached statistical significance ($\chi^2 = 6.53$, $p = 0.08$).

Teachers and researchers used fewer VVI pacemakers than did those not involved in research or teaching. The VVI mode was used in most cases by 88% of teachers and by 93% of nonteachers ($\chi^2 = 8.59$, $p = 0.035$). Researchers implanted fewer VVI pacemakers than did teachers, with 72% of researchers using the VVI mode in most cases. For those not involved in research, 92% used the VVI mode in most cases ($\chi^2 = 8.93$, $p = 0.03$).

Private practitioners implanted more DVI pacemakers than did physicians in other types of practice. Multispecialty groups used a higher percent of AAI (atrial demand) pacemakers. More than 12% of private practitioners (versus 3% of those not in private practice) used DVI pacemakers in more than half of their cases ($\chi^2 = 9.33$, $p = 0.025$). Of physicians practicing with a multispecialty group, 20% used the AAI mode in most cases. This is the only group in the sample that reported such a high percent of AAI pacemaker usage ($\chi^2 = 13.85$, $p = 0.001$).

Electrode malfunction (Table 5). The incidence of early endocardial electrode malfunction (dislodgment, perforation, dislocation or displacement) of ventricular and atrial grasping and nongrasping electrodes was measured and used as an indicator of the quality of electrode implantation. It was measured as an interval level variable and was redefined as ordinal for analytic purposes; malfunction was arbitrarily considered to be low if it occurred in 5% of cases or less, and high if greater than 5%.

Table 5. Early Endocardial Electrode Malfunction as Related to Electrode Type, 1981

Electrode Type	Grasping (%)	Nongrasping (%)
Ventricular	0.9	4.2
Atrial appendage	0.7	3.0

For the entire sample, no category of malfunction exceeded 4.2%. In fact, the malfunction rate for neither the ventricular grasping nor the atrial grasping electrode reached 1.0%.

Relation to physician specialty and implant volume (Table 6). The malfunction rate for ventricular grasping electrodes approached significance when related to physician specialty only for low volume implanters. Malfunction of ventricular grasping electrodes was highest for surgeons, 5% of whom experienced a rate of more than 5%, while only 0.1% of nonsurgeons reported a malfunction rate this high ($\chi^2 = 2.18$, $p = 0.13$).

Low volume implanters reported a significantly greater degree of malfunction of ventricular nongrasping electrodes than did those implanting more than 30 pacemakers per year, regardless of physician specialty. At least a 6% electrode malfunction rate was experienced by 22% of low volume implanters and 7% of high volume implanters ($\chi^2 = 20.71$, $p = 0.001$). When physician specialty was held constant, these differences between low and high volume implanters persisted. Almost 21% of low volume surgeons experienced a malfunction rate of more than 5% compared with 7% from high volume surgeons ($\chi^2 = 11.32$, $p = 0.001$). Similarly, 23% of low volume nonsurgeons reported a malfunction rate of at least 6% compared with 6% of high volume nonsurgeons ($\chi^2 = 6.50$, $p = 0.011$).

Size of implantation teams. The malfunction rate for ventricular nongrasping electrodes was also significantly related to the size of the implantation team. Twenty percent of team physicians versus 12% of solo physicians reported a malfunction rate of more than 5% ($\chi^2 = 5.72$, $p = 0.017$). When implant volume was held constant, this relation remained only for low volume implanters. Team physicians again experienced a higher rate of malfunction, with 26% of team physicians and 16% of solo physicians reporting a malfunction rate of more than 5% ($\chi^2 = 3.51$, $p = 0.06$). The relation between malfunction rate and the number of physicians on the implantation team was not significant for high volume implanters.

When the number of physicians on the implantation team was held constant, the relation between malfunction rate

Table 6. Early Endocardial Electrode Malfunction as Related to Implant Volume, 1981

	Fewer Than 31 Implants per Year			More Than 30 Implants per Year		
	All	Surgeons	Nonsurgeons	All	Surgeons	Nonsurgeons
Incidence of ventricular nongrasping malfunction						
0 to 5%	78.2%	79.4%	77.1%	92.8%	92.6%	93.6%
6%	21.8%*	20.6%*	22.9%†	7.2%	7.4%	6.4%

*p = 0.001; †p = 0.011.

and implant volume was not significant for solo physicians. For team physicians, however, the relation remained significant. Almost 26% of low volume team implanters reported a malfunction rate of more than 5%, while only 10% of high volume implanters did so.

Veterans Administration (VA) hospitals. These hospitals experienced more frequent malfunction of ventricular nongrasping electrodes than did other types of institutions. In the VA hospitals, team implanters and nonsurgeons reported considerably more malfunctions of ventricular nongrasping electrodes than did surgeons and solo implanters.

Of all physicians who worked primarily in VA hospitals, 38% reported a malfunction rate of more than 5%, compared with 15% of those listing another hospital type as their primary institution ($\chi^2 = 6.66$, $p = 0.009$). Forty-five percent of team physicians working in VA hospitals (versus 18% team physicians in other types of hospitals) reported a malfunction rate of more than 5% ($\chi^2 = 6.66$, $p = 0.019$). For nonsurgeons in VA hospitals, the proportion reporting a malfunction rate of more than 5% increased to 46%, compared with 16% of nonsurgeons not working in VA hospitals ($p = 0.019$)

Grasping versus nongrasping electrodes. Grasping electrodes were defined as those with *active* fixation elements, such as screws or barbs. Tined leads were considered to be nongrasping. There was a moderate correlation (Pearson product-moment correlation $r = 0.461$) between percent malfunction of atrial grasping and ventricular grasping electrodes for all physicians, and a small correlation between atrial nongrasping and ventricular nongrasping electrodes ($r = 0.244$). When physician specialty was held constant, however, those correlations changed considerably. For surgeons, malfunction of grasping electrodes (atrial and ventricular) was highly correlated ($r = 0.649$). When both the number of physicians on the implant team and physician specialty were held constant, the correlation coefficient for malfunction of grasping electrodes increased to 0.689 for solo surgeons and to 0.685 for team surgeons.

For nonsurgeons, on the other hand, the malfunction rate for nongrasping atrial and ventricular electrodes was moderately correlated ($r = 0.428$). In this case, however, the correlation coefficient did not change when the number of physicians on the implant team was held constant.

When the malfunction rate for atrial *grasping* electrodes was analyzed with respect to differences among subgroups of the sample, no significant differences were found because very few respondents reported such malfunctions.

Although the malfunction rate for *ventricular* nongrasping electrodes showed differences by physician specialty, volume and implantation team size, most of the differences in the malfunction rate for *atrial nongrasping* electrodes were observed among hospital types and for small subsets of the sample.

For all pacemaker implanters, the malfunction rate for atrial nongrasping electrodes was significantly higher in medical schools and lower in public hospitals. Of physicians working in a medical school, 27% experienced a malfunction rate of more than 5%, as opposed to 10% of those who did not work in a medical school ($\chi^2 = 10,23$, $p = 0.001$). For physicians working in a public hospital, the relation was reversed. Six percent of those working in a public hospital reported a malfunction rate of more than 5%, in contrast to 15% of those not working in a public hospital ($\chi^2 = 12.42$, $p = 0.001$). Nonsurgeons in public hospitals reported a lower incidence of malfunction than did surgeons. Only 3% of those nonsurgeons reported a malfunction rate of more than 5%, compared with 8% of surgeons.

When considering the entire sample, there were no differences in the malfunction rate for atrial nongrasping electrodes between those who did and those who did not work in a hospital affiliated with a medical school. For certain subgroups, however, the difference in malfunction rates was statistically significant. Nonsurgeons, for example, reported a malfunction rate of more than 5% in 25% of cases in a medical school hospital and 9% in other types of institutions ($\chi^2 = 5.50$, $p = 0.019$). For team nonsurgeons, the rate of malfunction was 31% ($\chi^2 = 4.68$, $p = 0.03$). Other variables were considered for inclusion as indicators of the quality of electrode implantation (for example, infection or ulceration as an indication for electrode change), but the number of responses to these survey items was insufficient for statistical analysis.

Usefulness of the manufacturer's sales representative. Significant differences were found in the attitudes of physicians toward the assistance of the pacemaker manufacturer's sales representative at the operating table. Surgeons were slightly more favorably inclined than nonsurgeons. Twenty-one percent of surgeons reported that they found the sales representative's assistance "very" useful, compared with 8% of nonsurgeons ($\chi^2 = 18.87$, $p = 0.001$). Teaching surgeons, however, found the sales representative much less useful (18% of teaching surgeons and 35% of nonteaching surgeons found the representative "moderately" useful). This relation approached statistical significance ($\chi^2 = 6.90$ and $p = 0.075$).

The most accurate discriminator of attitudes toward the sales representative was the 1981 implant volume, with low volume implanters reporting more favorable attitudes than high volume implanters. Almost 34% of low volume implanters believed the sales representative was "very" or "moderately" useful, whereas only 26% of high volume implanters felt so positive ($\chi^2 = 11.69$, $p = 0.009$).

The relation between attitude toward the assistance of a sales representative at the operating table and a hospital-based practice approached statistical significance, with hospital-based physicians demonstrating a considerably less positive attitude than those whose practice was not hospital-based. Almost 24% of the hospital-based physicians reported that the sales representative's assistance at the operating table was at least "moderately" useful, but 32% of those whose practice was not hospital-based also reported this level of usefulness ($\chi^2 = 6.75$, $p = 0.081$).

For nonsurgeons, attitude toward the sales representative and two types of practice, private and hospital-based, yielded statistically significant associations. Thirty-eight percent of nonsurgeons in private practice found the representative's assistance at least "moderately" useful, compared with 23% of nonsurgeons in other types of practice ($\chi^2 = 17.74$, $p = 0.001$). For hospital-based nonsurgeons, the sales representative was not considered as useful. Only 22% reported that the representative was at least "moderately" useful, compared with 31% of nonhospital-based nonsurgeons ($\chi^2 = 12.89$, $p = 0.005$).

Generally speaking, surgeons, low volume pacemaker implanters and physicians with a hospital-based practice were most likely to find the sales representative's assistance at the operating table useful. Surgeons involved in research and teaching were more likely to express a negative attitude toward such assistance.

Discussion

Methodologic problems. Such problems were encountered from the very beginning of this study, because no complete list of implanting physicians (our study population) was available. The list had to be compiled by us, with no guarantee that the list would be complete. Because we had no way of determining whether our list was complete, we were forced to assume that it was not. Without a complete list of our target population, a probability sample was not possible. Instead, we surveyed each physician on our list, asking also for the names of other pacemaker implanters. With this request, we hoped we would be able to add to our list, making it more comprehensive, if not complete.

As is the case with any mailed questionnaire, the 765 respondents constituted a self-selected sample. Because we had no data for nonrespondents, it was not possible to determine whether they differed from the respondents in any significant respect. It may be the case, for example, that physicians in one region of the country were underrepresented, or that very low volume implanters (for example, those implanting fewer than five pacemakers per year) did not feel that their data would contribute significantly to the survey and so did not respond.

Although a self-selected sample may introduce a selection bias into the design and thus impose certain limitations on the data, the results of research employing such a sampling design should not be dismissed. Rather, one should keep in mind the possibility of such limitations, especially when considering the interpretation of results.

We were able to compare demographic information for our respondents with the "best guess" of a major pacemaker manufacturer's marketing staff. Our respondents appear to be "representative" of the larger pacing community, in that the demographic profile of our respondents matches the manufacturer's profile rather closely on such variables as specialty, number of years in medical practice, number of years in pacing, pacing mode preference, type of practice and number of implants per year. Nevertheless, our findings must be viewed as estimations that may not be generalizable to the entire population of pacemaker implanters.

Rate of pacemaker implantation. In the United States, this rate has increased from about 309 implants per million population in 1978 to 518 implants per million in 1981. We estimate that, in 1981, there were 500,000 people in the United States with cardiac pacemakers.

Indications for pacing. Sick sinus syndrome as an indication for pacing has been increasing steadily over the past few years. It appears that this indication has reached its peak, however, as the expectation for 1985 is that it will decrease by about 3% from its 1981 level to approximately 45%. This decrease may be explained by the growing perception of the pacing public that pacing for sick sinus syndrome is not life-saving, as it is for complete heart block with Adams-Stokes seizures and, therefore, is indicated only to improve the quality of life. Furthermore, growing awareness of the tendency to overuse pacemakers has been stressed in a number of reports and commentaries (10). For these reasons, one might expect more strict indications for pacing to be applied.

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Pacemaker type and mode usage. *Dual-chamber and atrial pacing.* In 1981, the type of pacemaker usage reflected continuing technological advances in cardiac pacing. The use of dual-chamber and atrial pacing continued to increase, and is expected to reach almost 37% of all pacemaker implants by 1985, with a corresponding decrease in the use of VVI pacemakers. Some respondents (19%) felt that their experience with dual-chamber and atrial systems was insufficient to allow their use. These systems, nevertheless, now represent almost 10% of pacemaker implants. As the use of dual-chamber and atrial systems increases, so does the number of experienced physicians. We expect that by 1985, the percent of "inexperienced" physicians will have declined considerably, virtually excluding "insufficient experience" as a reason for not using dual-chamber and atrial pacing systems.

An additional 20% of physicians did not implant dual-chamber and atrial systems because the referring physician had not requested them. We believe that, in part, this may be a function of the physician's lack of familiarity with dual-chamber pacing or a belief that single-chamber pacing is simply good enough for almost everyone. Again, we expect that an increasing familiarity with dual-chamber pacing on the part of the physician will lead to an increase in the use of such pacemakers.

Programmable versus nonprogrammable pacemakers. Although almost all primary pacemakers implanted during 1981 were programmable (90%), 10% were nonprogrammable. Twelve physicians explained that they believed nonprogrammable VVI pacemakers were adequate. Virtually all physicians expressed confidence that multiprogrammability was "clinically important" for patients younger than 70 years of age, but 34% reported that multiprogrammability was either "unimportant" (7%) or only "slightly important" (27%) for patients older than 70 years.

It is likely that the 10% of nonprogrammable pacemakers were given to elderly patients for whom multiprogrammability was viewed as relatively unimportant. The elderly are often regarded as sedentary, inactive or even bedridden individuals, in whom rate support is the most that is needed from a pacemaker. It is sometimes even suggested that the elderly do not "need" dual-chamber pacemakers, and that such advanced systems are "wasted" on them.

Reuse of lithium battery pacemakers. The majority of respondents (82%) reported that they favored the reuse of lithium battery pacemakers. These results support those of an earlier smaller study in which 81% of the American physicians queried favored pacemaker reuse (Parsonnet and Crawford, unpublished data). There appear to be enough potential recipents of such pacemakers to justify a more intensive investigation of methods of preparing normally functioning pacemakers for reuse.

Implant experience and choice of pacemaker. The use of multiprogrammable and dual-chamber pacemakers was found to be related to the volume of a physician's implant experience. It was evident that physicians working alone and those implanting more than 30 pacemakers per year used significantly more multiprogrammable pacemakers than did team implanters and low volume implanters. If the number of pacemakers implanted in 1981 can be considered a measure of implant experience, then the relation between the use of multiprogrammable pacers and experience is clear. It may be that only those physicians with considerable experience and confidence in their ability to implant a pacemaker would work alone.

The relation between the use of DVI pacemakers and experience was more direct. More DVI pacers were implanted by physicians who had been in practice for more than 10 years than by those in practice 10 years or less. DVI pacemakers were used more frequently by those in private practice than by those not in private practice; multispecialty groups used more AAI pacemakers than did other practice types.

Electrode malfunction. We chose the incidence of early endocardial electrode malfunction (ventricular and atrial grasping and nongrasping electrodes) as a measure of the quality of electrode implantation, recognizing that this was only a rough indicator and only one aspect of quality. Volume and the quality of electrode implantation were found to be directly related for nongrasping ventricular electrode malfunction. The rate of malfunction decreased as volume increased, *regardless of physician specialty*. But, within the category of low volume implanters (30 or fewer implants per year), surgeons experienced significantly more malfunctions than did nonsurgeons. In addition, solo implanters experienced significantly fewer ventricular nongrasping electrode malfunctions than did team physicians. This lends further support to a previous suggestion that only experienced physicians, confident in their ability, would work alone. When implant volume was held constant, however, the relation between malfunction and the number of physicians on the implant team remained only for low volume implanters. As expected, we found that, in general, as implant volume (experience) increased, the malfunction rate decreased.

Electrode malfunctions were more frequent in Veterans Administration hospitals than in other types of hospitals, particularly for ventricular nongrasping electrodes. This was also true for nonsurgeons and team implanters working in a Veterans Administration hospital, who reported a higher malfunction rate than did surgeons and solo implanters. The higher malfunction rate for ventricular nongrasping electrodes implanted by teams provides additional support for our interpretation of the greater experience and confidence of the solo implanter.

Malfunctions of atrial nongrasping electrodes were most frequent in medical schools and least frequent in public hospitals. Nonsurgeons experienced higher malfunction rates

at a medical school affiliate; for team nonsurgeons, the incidence of malfunction was even higher (31% experienced a malfunction rate of more than 5%). Explanations for these discrepancies are not apparent at this time.

For the patient requiring a pacemaker with either atrial or ventricular nongrasping electrodes, the "best" implant situation would appear to be a public hospital setting and a solo nonsurgeon with a large implant volume. This combination produced the lowest incidence of early endocardial malfunction. The "worst case" appears to be implantation by a team surgeon with a small implant volume, working in a Veterans Administration hospital or a medical school.

A patient in the operating room under the care of a low volume physician or a nonsurgeon with a hospital-based or private practice may find that a manufacturer's sales representative is also present. Physicians in these categories, more than any others, were more likely to accept the sales representative's assistance at the operating table.

Value of surveys of pacing trends and techniques. Periodic surveys of pacing trends and techniques provide valuable information and insights into the state of the art of cardiac pacing. This medical specialty is growing so rapidly that it seems that new pacemaker hardware, diagnostic techniques and more sophisticated pacemaker programmers are being marketed daily. Physicians implanting pacemakers may find it difficult to keep up with these new developments and know what equipment, procedures and techniques are being used and found effective by their peers.

Periodic surveys of pacing trends and techniques are one way in which physicians can share information with others in their specialty. Internationally, it allows the United States to share valuable information and experience with other countries. Such sharing is important to physicians comitted to cardiac pacing and to the quality of care and well-being of the pacemaker patient.

The methodologic limitations inherent in this research prohibit us from generalizing to the entire community of pacemaker implanters. Because physicians involved in cardiac pacing are not required to meet any particular national or regional standards, complete any special course of training or apply for certification from any board or organization, a complete list of "pacemaker physicians" is unobtainable. Had such a list been available, a stratified random (probability) sample would have been the design of choice, thus permitting us to extrapolate and generalize to the entire population of implanting physicians with far greater confidence.

Future needs. Although the data we present for the United States at each International Symposium are more complete than those of the preceding survey and based on an increasingly "representative" sample of physicians, major improvements in the methodology of such a large and comprehensive survey would make the data even more valuable. This cannot be accomplished, however, unless a truly representative sample can be drawn from the population. A prospective data base, perhaps in the form of a national pacemaker registry, would be a far more efficient method of data collection. Retrospective survey analysis and its inherent limitations would cease to be problematic because data would be retrievable from a centralized source. Benefits from such a system would accrue not only from ease of retrieval, but also in terms of the accuracy and completeness of the data.

The survey for 1981 has elicited important trends in the practice of cardiac pacing. It is hoped that better ways to obtain useful information on pacing practices will become available by the time we begin data collection for the 1986 survey.

Summary and Conclusions

The 1981 United States Survey of Cardiac Pacing Practices has revealed several important facts and trends, as well as expectations for the future. It has identified deficiencies and problem areas that require attention, particularly the rate of electrode malfunction, which has been assumed to be an index of the technical skill of the implanting physician and thus a factor in the quality of patient care.

Although approximately half of the hospitals in the United States performed pacemaker implantations, 75% of these institutions did not have a special pacemaker department or service and approximately 50% did not have specific written guidelines governing surgical privileges for pacemaker implantation. Of the approximately 5,600 implanting physicians working in these hospitals, more were cardiothoracic or general surgeons than were nonsurgeons (cardiologists or internists). The rate of primary pacemaker implantation had increased from 309 implants per million population in 1978 to 518 per million population in 1981 when there were about 500,000 people in the United States with cardiac pacemakers.

Indications for pacing had changed, as had the equipment and methods used for diagnosis and treatment. Sick sinus syndrome, which represented about 23% of pacing indications in 1978, represented 48% in 1981, while pacing for the treatment of tachyarrhythmias had begun to emerge as a new indication (about 2%). Dual-chamber pacing had grown in popularity to approximately 10% of implants and is expected to increase to 37% by 1985, with a corresponding decrease in the use of VVI pacemakers.

Between 1978 and 1981, the rate of usage of programmable pacemakers increased from 39 to 90%, yet nonprogrammable systems were still used in 10% of primary implants. Many physicians did not take full advantage of programming potentials as evidenced by the fact that almost half of the programmable pacemakers implanted were not reprogrammed within the first 3 months and 30% were *never* reprogrammed.

Nevertheless, multiprogrammability was considered "clinically important" by many respondents. Troubleshooting of pacemaker problems and adjustments for physiologic need were considered to be the most useful aspects of multiprogrammable systems, while "fine tuning" soon after implantation was considered the least useful. These attitudes may explain the frequent failure to reprogram some units, with programming capabilities reserved for solving clinical problems and not applied to refinements, such as the extension of pacemaker life by reducing the stimulus output amplitude. Similarly, while multiprogrammability was considered important for patients under the age of 70 years, it was felt to be relatively *unimportant* for older patients. Evidence that such attitudes were justifiable was not obtained from this survey.

Our results show that the quality of lead implantation, based on the frequency of early electrode malfunction, was better in the hands of those who performed a high rather than a low volume of pacemaker implantation. This was also true of implanting physicians who worked alone as compared with implanting teams, and for public and community hospitals as compared with Veterans Administration hospitals and medical schools.

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