a secondary place. The number of beds required for psychiatric and mentally subnormal patients is large because they comprise a considerable part of the total hospital population; and with the continued decline of acute illness their contribution, together with that of the aged sick, will be even larger. Medical research has not yet been very successful in unravelling the nature of these problems, and many patients still require prolonged care. But this is not a reason for accepting an inferior standard of care, and given well-designed services there are no financial or other grounds for not admitting all types of patients, including the mentally subnormal, at the same hospital centre in approximately the proportions in which they are found in the general population.

Summary

Investigation of the medical, nursing, and social needs of all Birmingham patients (1,652) in hospitals for the subnormal showed that only about half needed the kind of care—mainly basic nursing and psychiatric supervision—which made it necessary for them to be in hospital. The other half of the patients required training and occupation—both inadequately provided in hospital—in a sheltered environment with, in some cases, simple personal attention described as checking and counselling.

In accord with the recommendations of HM(65)104, it is suggested that hospital responsibility should be restricted to

patients needing medical and nursing care and that the remainder should be transferred to local health, welfare, and education authorities. The reduction in the number of mentally subnormal patients in hospital would make it possible to care for them with all other hospital patients at a common centre. Only in this way will it be possible to focus research interest on the problems of the subnormal and to raise the standard of their care to an acceptable level.

For collaboration in the assessment of patients' needs we are indebted to the medical superintendents (Drs. R. A. Browne, A. P. Buchan, T. Crowley, A. S. Patterson, and R. J. Stanley) and staffs of the mental subnormality hospitals in the Birmingham Region. Dr. Stanley also provided valuable advice about the organization of the inquiry and the interpretation of its results. The data were collected and analysed with the help of Dr. W. L. Gordon, Miss Ida Giles, and Mrs. Betty Mann. National statistics relating to patients in mental subnormality hospitals were made available by Miss E. M. Brooke, of the Ministry of Health. Finally we should like to express our indebtedness to Dr. T. L. Pilkington for giving us the results of his investigation and for his helpful comments on our own.

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Clinical Application of Demand Pacemakers

EDGAR SOWTON,* M.D., M.R.C.P.

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Treatment of patients with chronic complete heart block by artificial pacemakers reduces the one-year mortality from approximately 40% to approximately 17% (Sowton, 1967), and with modern techniques and apparatus the morbidity is now low. Parsonnet, Gilbert, and Zucker (1966) reported that after the first few months have been successfully negotiated there is a high probability that one or two uneventful years of stable pacing will follow, and Chardack, Gage, Federico, Schimert, and Greatbatch (1966) claim a better than 90% chance that any individual patient will experience uninterrupted pacing for at least 18 months.

One problem found with patients treated by fixed-rate pacemakers is that sinus rhythm may return, so that competition occurs between natural and artificial pacemakers. This leads to an irregular ventricular rate, palpitations, variations in systemic pressure which occasionally cause symptoms, and the possibility of dangerous arrhythmias provoked by pacemaker stimuli falling in the vulnerable period of the cardiac cycle (Sowton, 1965). These risks are especially important when short-term pacing is carried out in patients with temporary heart block following cardiac infarction (Harris and Bluestone, 1966), because the threshold for arrhythmias is considerably lower than normal and the chances of sinus rhythm returning are considerably higher.

Competition can be avoided by the use of a pacemaker which automatically detects any spontaneous activity and cannot

deliver a stimulus until a preset interval has elapsed: such pacemakers are referred to as "demand," "standby," "ventricular-inhibited," or "R-top" units. A pacemaker capable of functioning in this way was described as early as 1956 (Leatham, Cook, and Davies, 1956), and several other external demand units have been described more recently (Nicks, Stening, and Hulme, 1962; Zacouto, 1963; Lemberg, Castellanos, and Berkovits, 1965). Completely implanted demand pacemakers have also been produced, but experience is still limited. Chardack *et al.* (1966) have reported successful results in animal experiments with a Medtronic unit and have implanted similar units in patients (personal communication, 1967). Experience in animals with American Optical miniaturized demand units has been reported by Goetz, Dormandy, and Berkovits (1966), and these units have been used externally in patients; a very few of these pacemakers have also been completely implanted (Berkovits, personal communication, 1967). Most experience under clinical conditions with fully implanted units in patients has probably been gained with the Cordis Ventricor II Standby pacemaker, and Parsonnet, Zucker, Gilbert, and Myers (1966) have reported successful results for periods of over a year. In the present paper some of the clinical experience at the National Heart Hospital and Institute of Cardiology with various types of demand pacemakers is described.

Material and Methods.—The patients were all treated at the National Heart Hospital, initially as inpatients and subsequently followed in the pacemaker clinic. All had had complete heart

* Institute of Cardiology and National Heart Hospital, London W.1.

block at some period and all those treated with long-term pacing had a history of Stokes-Adams attacks. The results are best considered in two groups.

Short-term Demand Pacing

Six patients were paced in this way for periods of up to 21 days because of acute block following cardiac infarction, and 15 patients were paced for periods of up to 16 days as a preliminary measure before long-term pacing. Temporary external units have been mainly of two types. Most patients were treated with the commercially available version of the pacemaker designed by Davies (Leatham *et al.*, 1956) in which the E.C.G. input is obtained from ordinary limb leads. More recently a pacemaker designed and built at the Institute of Cardiology has been employed (Norman and Obeyesekera, 1967; Sowton and Norman, 1967). A few patients were also paced with American Optical monitor pacemakers, Model 10750, which incorporate a demand pacemaker.

A large number of measurements of the R wave detected from different transvenous electrodes in the right ventricle have now been made and indicate the amplitude ranges from 2 millivolts to above 30 millivolts under different conditions: even higher values may be found with intramural leads. Since the amplitudes recorded from transvenous electrodes were usually more than 5 millivolts, it is apparent that demand pacemakers should be inhibited by an input signal of about 1.0 millivolts, and this level has proved satisfactory in practice. The rate of rise of the R wave is also important and maximum sensitivity of this pacemaker is achieved at a frequency of 30 cycles/sec.

In all patients competition was completely avoided with each of the three types of external pacemaker. Stable pacing was achieved with each of the three units and there was no detected

FIG. 1.—On-demand pacing. E.C.G. from a patient with intermittent heart block. After 1.6 seconds asystole pacing automatically starts but the pacemaker is again inhibited by the return of sinus rhythm.

incidence of failure to pace when the preset time interval following an R wave was exceeded.

With the Davies pacemaker the interval following an R wave before pacing begins can be adjusted within wide limits, and this interval is independent of the stimulation rate; Fig. 1 illustrates a typical E.C.G. obtained from a patient being paced

FIG. 3.—E.C.G. obtained with Institute of Cardiology demand pacemaker. The pacing stimuli are provided as necessary to prevent the heart rate falling below 60 beats per minute.

with this apparatus. There are several features of this pacemaker which are not in keeping with modern techniques, notably the use of a relay in the circuit and the need for skin-contact electrodes to detect the E.C.G., but in our experience it has proved reliable and has been in clinical use until recently.

The American Optical demand pacemaker also suffered from the disadvantage that skin-contact E.C.G. electrodes are used to detect spontaneous cardiac activity; movement of the patient may produce artifacts which inhibit the pacemaker, and there is the possibility that displacement of one E.C.G. pick-up

electrode resulting in loss of the input signal allows the pacemaker to stimulate and produce competition. Apart from this disadvantage, however, the pacemaker functions satisfactorily.

The Institute of Cardiology demand pacemaker also has a control which adjusts the interval following a spontaneous R wave before pacing impulse is delivered; in this pacemaker this interval is not independent of the pacing rate, so that a simple control determines the minimum ventricular rate below which the pacemaker stimulates. The pacemaker itself (Fig. 2) detects

FIG. 2.—Institute of Cardiology demand pacemaker in use. Spontaneous cardiac activity is monitored via the same electrode used for pacing.

spontaneous cardiac activity via the right ventricular transvenous electrode, which is also used for stimulating, and so avoids the complexity associated with E.C.G. limb leads. The pacemaker has proved extremely simple in use; all that is necessary is for the rate control to be set to the minimum acceptable ventricular rate. If the spontaneous rate is above this level the pacemaker is completely inhibited, but if the spontaneous rate falls below the minimum then the pacemaker provides such stimuli as are necessary to maintain the rate at this minimum level. A typical E.C.G. recorded with this pacemaker is shown in Fig. 3.

Long-term Demand Pacing

Seven patients have been treated with fully implanted demand pacemakers for periods of up to 10 months. Two types of implantable demand pacemakers have been used, in each case detecting the spontaneous R wave and stimulating the heart through a right ventricular transvenous electrode. In five cases the pacemaker was a Cordis Ventricor II and in two cases a Medtronic demand pacemaker. Two prototype miniaturized

demand pacemakers produced in the medical physics department of the University of Groningen, Holland, were also used in six patients for periods of up to 10 days; these were attached to transvenous electrodes but were carried externally.

Both types of implanted pacemakers have performed satisfactorily and competition has been avoided in all patients. The time interval which must elapse before a stimulus is produced is such that the minimum ventricular rate is 70/min. with the Ventricor II and the Groningen University pacemakers and 60/min. with the Medtronic. Spontaneous sinus rates in these

patients occasionally fell below these levels, particularly during sleep, so that paced activity occurred from time to time apart from development of transient heart block. In no case did this result in competition or unpleasant symptoms, though the patients were able to recognize that a particular ventricular beat was paced rather than spontaneous; they were presumably able to make the distinction because of the longer diastolic pause before the first paced beat and also because the paced beat was not preceded by a suitably placed atrial contraction and consequently resulted in a smaller stroke volume and a reduced systolic blood pressure.

During periods of normal sinus rhythm an implanted demand pacemaker is inhibited and normal E.C.G. records therefore give no indication of its presence. The Groningen University model contains a magnetically operated switch which bypasses the demand facility, so that the unit temporarily operates as a conventional fixed-rate pacemaker; application of an external magnet over the pacemaker during E.C.G. recording thus enables a check to be made that the pacemaker is functional. A similar switch is incorporated in some of the American Optical pacemakers used by Goetz *et al.* (1966), but the Cordis and Medtronic units used in these patients do not have this feature. The function of these pacemakers can be checked by manoeuvres which slow the heart below the inhibiting rate so that the pacemaker begins to stimulate. Carotid sinus massage was usually adequate in the cases described here, but occasionally a slow injection of 2–10 mg. of Tensilon (edrophonium chloride) was needed; this produced transient slowing and allowed the pacemaker to function for two or three beats. The ideal dose of edrophonium is that which does not quite slow the heart beneath the inhibiting rate for the pacemaker, so that carotid sinus massage can be used in addition to produce an R–R interval which will cause the pacemaker to stimulate.

Discussion

Competition can occur only when significant non-paced cardiac activity is present in a patient with a fixed-rate pacemaker. The major risk of competition is that a pacemaker stimulus falling during the vulnerable period may provoke fatal ventricular fibrillation, and this is most likely to occur when the cardiac threshold for ventricular fibrillation is unduly low. This situation arises when the patient has been given cardiotoxic drugs or has some condition such as acute myocarditis or recent ischaemic damage. The dangers of pacemaker-induced ventricular fibrillation are particularly great after cardiac infarction and in the immediate postoperative phase after the surgical implantation of a pacemaker with attachment of electrodes to the myocardium (Sowton, 1965).

About 25% of all patients with complete heart block who are considered for long-term artificial pacing return to sinus rhythm, at least for short periods, and, as probably 12,500 patients in Britain have chronic complete heart block, there are about 3,000 patients with intermittent block. About two-thirds of these patients may be expected to suffer from Stokes–Adams attacks, and this suggests that artificial pacing is at present indicated for some 8,000 patients in the British Isles, of whom 2,000 should be treated with demand pacemakers. Unfortunately there is no known way to distinguish patients who may return to sinus rhythm once pacing has started, and so there is a case for treating all patients in need of long-term pacing with demand pacemakers as soon as it has been demonstrated that these units are at least as reliable as the simpler fixed-rate type. It should be noted that both atrial-triggered and ventricular-

triggered pacemakers also function as demand pacemakers when necessary, but these units are outside the scope of the present paper.

Demand pacemakers are more complicated than simple fixed-rate units, but the implanted types used in the present study are based on the well-proved circuits of the standard Cordis and Medtronic pacemakers. Much of the manufacturing technique and accumulated experience obtained with standard pacemakers has been incorporated in the production of these demand units, in addition to the similarities of much of the circuitry. Since each of the basic pacemakers concerned has a good reputation for reliability, a lifetime of two years for the implantable demand units does not seem unrealistic; however, until actual experience with a large number of units under clinical conditions over this period of time has been obtained, reliability figures must remain hypothetical. Early versions of implantable demand pacemakers have proved unduly sensitive to interference from external electrical fields and several changes in design have been recently introduced to overcome this problem. In none of the cases described here have the patients noted any symptoms related to external interference with pacemaker function, but until wider experience is available it seems wise for implanted demand pacemakers to be used only at hospitals which possess the necessary electronic and medical experience to carry out frequent follow-up checks on the patients. The external demand units currently available have proved very reliable, and it is recommended that they be used in preference to fixed-rate pacemakers in all patients when the threshold for ventricular fibrillation is low.

Summary and Conclusions

Demand pacemakers which do not stimulate during spontaneous cardiac activity are theoretically indicated for all patients treated with short-term pacing and for many patients needing long-term pacing.

A demand pacemaker for short-term pacing has been developed and shown to be clinically reliable. The stimulating electrode is also used as an intracardiac E.C.G. lead to monitor spontaneous activity.

Twenty-one patients have been treated for periods of up to 21 days with external demand pacemakers connected to transvenous right ventricular electrodes.

Seven patients have been treated with fully implanted demand pacemakers for periods of up to 10 months. If these units prove to be reliable over longer periods demand pacemakers should be used for most patients at present treated with conventional fixed-rate units.

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