Ventricular-triggered Pacemakers: Clinical Experience

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It is now generally agreed that the presence of symptoms is an indication for long-term pacing of patients with complete heart block, and that this treatment lowers the mortality considerably (Char-dack *et al.*, 1966; Sowton, 1967a). An appreciable proportion of paced patients has intermittent atrioventricular conduction so that if a fixed rate pacemaker is implanted there is competition between natural and artificial pacemakers. This frequently produces palpitation, sometimes causes large swings in blood pressure, and very occasionally results in dangerous ventricular arrhythmias due to stimulation within the vulnerable period (Tavel and Fisch, 1964). Competition can be avoided in several ways, one of which is the use of demand pacemakers which do not stimulate the heart unless a fixed period without spontaneous activity occurs (Parsonnet *et al.*, 1966; Sowton, 1967b). An alternative approach, due to Neville (Neville *et al.*, 1966), is for the pacemaker to be triggered by spontaneous ventricular potentials and then to deliver an impulse to the ventricle immediately. This impulse falls ineffectively within the absolute refractory period and so cannot cause a competing rhythm, nor stimulate during the vulnerable period. So long as sinus rhythm persists the pacemaker follows the ventricular rate exactly; if a spontaneous ectopic beat occurs this, too, will trigger the pacemaker so that the stimulus falls harmlessly during the refractory period. If complete heart block returns, so that no spontaneous QRS complex arises during a preset time interval, the pacemaker begins to stimulate the ventricle at a fixed rate. The time interval is directly related to the fixed pacing rate, and pacemakers of this type provide a limit below which the ventricular rate cannot fall. If conducted or ectopic beats return the pacemaker will again be immediately triggered at the spontaneous rate.

The use of atrial-triggered pacemakers, which

behave as an artificial bundle of His, is well established (Lagergren *et al.*, 1966; Nathan, 1967). Pacemakers of this type are relevant to the present paper since they can also be used as ventricular-triggered pacemakers. For this application the electrode intended for detection of atrial activity is placed on the ventricle instead of on the atrium, so that the pacemaker responds to the QRS instead of to the P wave potentials. The pacemaker thus functions in a similar manner to a normal ventricular-triggered unit, except that the stimulus is delivered during the S-T phase of the electrocardiogram instead of during the QRS. As before, the pacemaker stimulates at a fixed rate if the ventricular rhythm falls beneath a limiting value. The advantage of using such pacemakers in this way instead of as atrial-triggered units is that no pick-up electrode need be attached to the atrium. The pacemaker can be used to replace a fixed-rate unit provided two ventricular leads are available—one for connexion to the 'atrial' input and one for delivery of the stimulating impulse to the ventricle. An entirely new pacing system of this type can be implanted more easily than for atrial-triggering, since both 'atrial' and ventricular electrodes can be attached to the heart through the diaphragm. Furthermore, the method is applicable even in the presence of atrial dysrhythmias and atrial fibrillation. The main disadvantages are that the physiological control of heart rate is not achieved when the pacemaker is used in this way, and correct atrioventricular timing is also missing so the atrial transport mechanism is ineffective. These four different modes of pacing are illustrated in Fig. 1. In this paper the clinical experience at the National Heart Hospital over the past year with ventricular-triggered pacemakers is reviewed.

MATERIALS AND METHODS

Several different types of ventricular-triggered pacemaker have been utilized. Patients have been paced

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FIG. 1.—Diagrammatic representation of four types of pacing which avoid competing rhythms. (1) Pacemaker is inhibited by spontaneous QRS, but stimulates at a fixed rate if QRS does not occur. (2) Pacemaker is triggered by spontaneous QRS and delivers an ineffective stimulus; if no QRS appears the pacemaker stimulates the ventricle at a fixed rate. (3) Atrial-triggered pacemaker detecting spontaneous atrial activity and stimulating ventricle after a fixed delay equivalent to the P-R interval; in sinus rhythm the stimulus is ineffective. If no atrial potential is detected the pacemaker stimulates the ventricle at a fixed rate. (4) Atrial-triggered pacemaker arranged with the atrial pick-up electrode on the ventricle instead of the atrium. The pacemaker now functions as a ventricular-triggered pacemaker with a delay between detection of ventricular activity and delivery of the pacing stimulus. If no QRS appears the pacemaker stimulates at a fixed rate.

for short periods of time with pacemakers manufactured at the University of Pisa (Denoth and Donato, 1967), but these pacemakers are still under development and have not been implanted. Sixteen patients have been paced with fully implanted units; there were 10 men and 6 women, with ages ranging from 42 to 82. All were initially referred because of Adams-Stokes attacks, and complete heart block had been documented by electrocardiogram at some time in every case. The indications for using ventricularly-triggered pacemakers were the intermittent presence of sinus rhythm, multiple ectopic beats during temporary fixed rate pacing, or electrocardiographic evidence of AV conduction in the recent past. A history of angina pectoris was a contraindication, and no such patients are included in this report.

Following implantation of the units all patients were followed in the pacing clinic, where tests of pacemaker

function were regularly carried out. The techniques and results of testing these and other implanted pacemakers have previously been briefly described (Sowton, 1967c) and will be fully reported elsewhere.

Nine patients have had Cordis Ectocor* (previously known as Ventricor 111) pacemakers implanted for periods of up to 12 months. The results have so far been very satisfactory, with all pacemakers functioning correctly. No patient has had competition and there have been no known instances of ectopic beats which failed to trigger the pacemakers. None of these Ectocors have failed and there has been no failure of the Cordis electrodes. In one patient pacing ceased after 7 weeks because of a high threshold, but the pacemaker was merely transferred from endocardial to epicardial

* Supplied by Kimal Scientific Products Ltd., 19, Southfield Close, Hillingdon.

FIG. 2.—Electrocardiogram of a patient with a Cordis Ectocor ventricular-triggered pacemaker. Pacing at the fixed rate is seen, with one spontaneous ectopic beat which triggers the pacemaker.

FIG. 3.—Electrocardiogram of a patient with a Cordis Atricor acting as a ventricular-triggered pacemaker. The patient is in sinus rhythm and the impulse is delivered during the S-T phase, too early to cause ventricular depolarization.

electrodes and continues to function normally after 3 months. A typical electrocardiogram of a patient with a ventricular-triggered pacemaker is shown in Fig. 2.

Two patients have been treated with Elema-Schönander EM 143† ventricular-triggered pacemakers. In both cases the Elema transvenous electrode was used and the pacemakers are functioning normally after approximately 3 months.

Five patients have been treated with Cordis Atricor atrial-triggered pacemakers with the atrial pick-up electrode attached to the ventricle; a typical electrocardiogram is shown in Fig. 3. The longest time to date that an Atricor has been functioning as a ventricular-triggered unit in this series is 10 months. One patient died unexpectedly on the 5th post-operative day, but no electrocardiogram of the moment of death is available. Necropsy disclosed no cause for death, and the entire pacing system was apparently functioning normally

after death so no explanation is available for this incident; a rapid ventricular dysrhythmia seems most likely. Subsequent testing of the Atricor disclosed no electronic fault. In all other patients the use of an Atricor for ventricular triggering has been very satisfactory. No competition has occurred and pacing has always been established when the spontaneous rhythm failed.

DISCUSSION

Clinical experience with ventricular-triggered units has so far been very satisfactory. The advantages as compared with true demand (i.e. inhibited by spontaneous ventricular activity) units are that an electrocardiogram shows the pacemaker to be functioning whether the patient is in block or in sinus rhythm, that pacemaker testing by analysis of the impulse detected from the limb electrodes (Sowton, 1967c) is considerably simpler, and that

† Elema-Schönander AB, Stockholm-Solna, Sweden.

the heart rate can be easily increased after pacemaker implantation by the application of low voltage (2V) impulses to the skin over the heart from an external adjustable second pacemaker. The disadvantages are that the battery lifetime will probably prove to be shorter than for demand units and that long-term disadvantages from continual stimulation of the heart during its refractory period may appear. In practice, both demand and ventricular-triggered types of pacemaker have functioned well in the patients attending this pacemaker clinic, and there is no evidence so far of the superiority of either method.

The problem of interference with pacemaker function from external electrical fields is particularly relevant to triggered pacemakers. Early models of both demand and ventricular-triggered types were prone to this fault, and there are instances of demand pacemakers being inhibited by electric razors, and of both types being accelerated by 'electrically noisy' equipment, such as car ignition systems and heater motors. No patient in this series has experienced such an incident so far as can be determined and continual improvements in pacemaker circuitry by the manufacturers are reducing the risk still further.

The reliability of these pacemakers is still unknown, apart from the Atracor which has now been in clinical use for many years and is known to have an excellent record (Nathan, 1967). The Elema-Schönander EM 143, and the Cordis Ectacor have been developed from the corresponding atrial-triggered pacemakers (Elema EM 141 and Cordis Atracor, respectively) and utilize much the same circuit and packaging. It does not seem unreasonable to anticipate similar reliability in the atrial-triggered units, and lifetimes should also be approximately the same. In practice, this probably means that the Ectacor should be changed after 24 months and the EM 143 earlier than this. Firm conclusions concerning reliability and lifetime obviously must be postponed until considerably more clinical experience has been obtained.

SUMMARY AND CONCLUSIONS

Sixteen patients with intermittent heart block have been treated for up to 10 months with 3 different types of fully implanted pacemakers which are triggered by spontaneous ventricular activity. No competition has occurred and pacing has regularly started when necessary. The reliability of these units has been satisfactory to date. Ventricular-triggered pacing is as satisfactory as demand pacing for patients with fluctuating sinus rhythm and heart block.

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