THE USE OF IMPLANTABLE CARDIAC PACEMAKERS IN THE TREATMENT OF COMPLETE HEART BLOCK*

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In patients with complete heart block the clinical course is influenced by the presence of frequent attacks of syncope (Stokes-Adams attacks) or by associated heart failure. If untreated, the prognosis is poor.[1-4] Few survive more than 3 years after the condition is diagnosed or after the first syncopal attack.[1] Of patients admitted with complete heart block (and excluding those with acute myocardial infarction, digitalis toxicity and congenital heart disease), one-third die during their first hospital admission, and one-half die during the first year of observation. Moreover, the patients live a life of poor quality, suffering from weakness and cardiac failure and with the fear of recurrent syncopal attacks (Fig. 1).

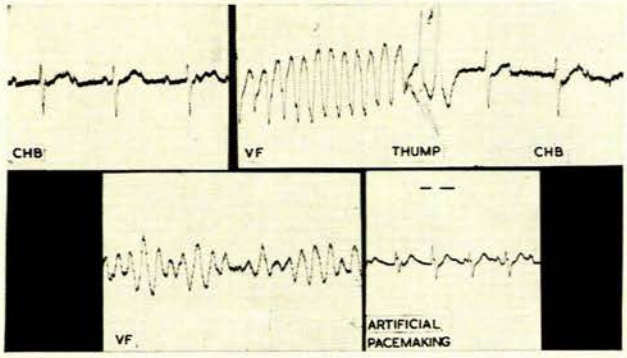

Fig. 1. Typical arrhythmias during a Stokes-Adams attack in a patient with complete heart block. *Top left*: Complete heart block with a ventricular rate of 40/min. *Top right*: Ventricular flutter during a Stokes-Adams attack terminated by a thump on the chest. *Bottom left*: Another episode of unconsciousness associated with ventricular fibrillation. *Bottom right*: Transvenous endocardial electrode wire pacing—ventricular rate of 75/min.

Long-term cardiac stimulation, with implantable pacemakers, myocardial electrodes, transvenous electrode wires and other electronic devices, has been established as fairly safe and effective in preventing these syncopal attacks. To prevent seizures due to ventricular standstill or fibrillation, the unreliable intrinsic ventricular pacemaker can be replaced by a reliable electrical unit, which will drive the ventricle continuously and indefinitely[5] (Figs. 1 and 2).

Treatment of intractable Stokes-Adams attacks by electrical stimulation was first suggested by the work of Callaghan and Bigelow[6] who carried out studies on animals with intact conducting tissues. Zoll, in 1952,[7] described an instrument for applying stimuli of high voltage via the skin in patients with cardiac arrest. Weireich, Gott and Lillehei[8] used a myocardial electrode and artificial pacemaker to control the heart rate in patients with surgically induced heart block. Furman and Robinson[9] in 1955 passed an electrode catheter into the right ventricle to control the heart rate. In 1960, Chardack *et al.*[10] first reported on the use of an intrinsically-powered circuit as a pacemaker. Since then, a variety of devices have become available for direct cardiac pacing using internal[11-22] or external[23-27] control circuits.

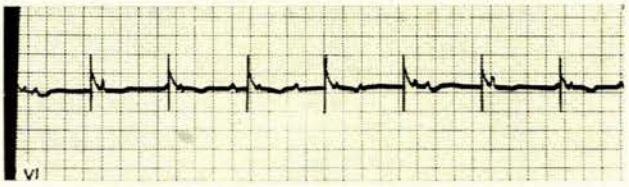

Fig. 2. Electrocardiogram taken during satisfactory pacemaking. There is independent atrial activity at a rate of 75/min. The equiphasic signal at 80/min. is the impulse from the pacemaker generator. This is followed by a stimulated ventricular complex.

As a result of extensive investigation and development, 4 systems of cardiac pacing are available at present.

1. Implanted electrodes with an external source of power.[28] This method carries a high risk of infection from poor sealing of the wire electrode as it passes through the skin. Also venous thrombosis develops from prolonged use of an indwelling venous electrode in the arm.
2. An implanted pacemaker wire with an electrical receiver and an external power source.[23-27] This method has many advantages, but it requires thoracotomy and a large powerful external power source.
3. A self-powered completely implantable transistorized generator using endocardial or epicardial pacing.[11-15,19-22] This system is limited by the life expectancy of the battery unit.
4. A system of synchronous pacing which also employs a self-powered unit.[16,17] The pacemaker is triggered by the atrial P wave so that the atrial contraction precedes the succeeding ventricular beat and acts as a booster pump. This is the pacemaker of the future but at present requires at least 2 sets of myocardial electrodes and a complicated electronic circuit.

We have used system 3 with epicardial electrodes implanted in the myocardium at the time of thoracotomy,[29,30] or with a long-term transvenous endocardial pacemaking wire[20-22] (Figs. 3-6). In each instance the power unit was implanted in the axilla or abdominal wall.

At present no ideal or completely reliable system is available and we will describe our personal experience and difficulty in 13 patients who have been treated between

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September 1963 and April 1965. Our experience with temporary pacemaking has been reported.[31]

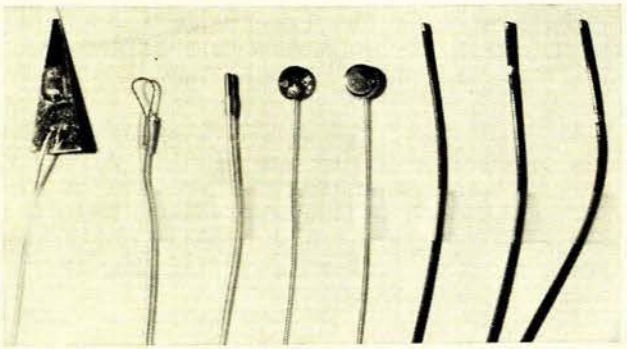

Fig. 3. Pacemaking electrodes used at Groote Schuur Hospital. From left to right: (*i*) Elema subcutaneous indifferent electrode, (*ii*) St. George's (Devices') subcutaneous indifferent electrode, (*iii*) Elema endocardial pacemaking wire electrode (sutured to the epicardium), (*iv*) and (*v*) Inner and outer surfaces of the Elema epicardial electrodes, (*vi*) C50, USCI, unipolar endocardial pacemaking wire electrode, (*vii*) C51, USCI, bipolar endocardial pacemaking wire electrode, (*viii*) C52, USCI, bipolar endocardial pacemaking wire electrode.

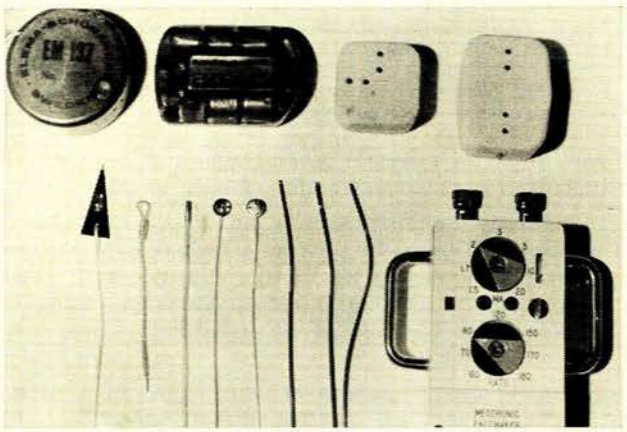

Fig. 4. Pacemaking generators and electrodes at Groote Schuur Hospital. *Top row* (left to right): Elema 137 abdominal generator; Elema 139 abdominal generator; St. George's (Devices') axillary generator; St. George's (Devices') abdominal generator. *Bottom row*: (*Left*) Pacemaking electrode wires arranged in the same order as Fig. 3. (*Right*) 'Medtronic' external pacemaker generator for temporary transvenous pacing showing the variable rate and current control.

CLINICAL MATERIAL AND RESULTS

Thirteen patients have been treated with implantable cardiac pacemakers during the period under review, and in one other case temporary pacing only was used. Their ages ranged from 57 to 81 with a mean of 66 years. The patients had permanent, chronic, complete heart block and only one had a clear history of myocardial infarction. Ischaemic heart disease was present in one other. The pacemaker was inserted as an emergency procedure in 12 of the patients and in one as a definitive procedure for intractable heart failure. Five of the former were also in heart failure at the time of pacemaker insertion.

Details of additional clinical features are listed in Table I. One patient (C.B.) had several other pathologies as well as complete heart block. He died of a cerebrovascular accident. Another (F.H.) had a carcinoma of the face and died at home 6 months later from a massive haemorrhage. One (F.A.) had a carcinoma of the breast for which a radical mastectomy had been performed. She died of a Stokes-Adams attack. Two other patients have required major surgery. G.H. had a hemicolectomy for carcinoma of the colon. The neoplasm has been completely removed. E.R. has had a temporary colostomy for diverticulitis which was subsequently closed. One patient (E.T.) had Parkinson's disease.

The clinical features were typical in each patient; a slow heart rate (25 - 40) which increased only slightly on exercise,

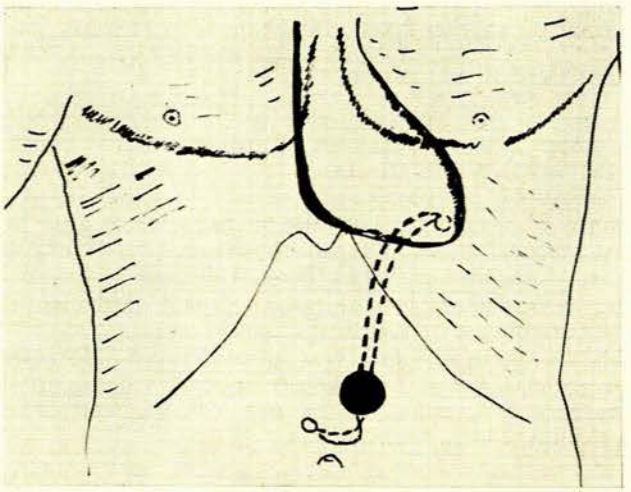

Fig. 5. The abdominal implanted pacemaking generator with epicardial electrodes and a subcutaneous indifferent electrode.

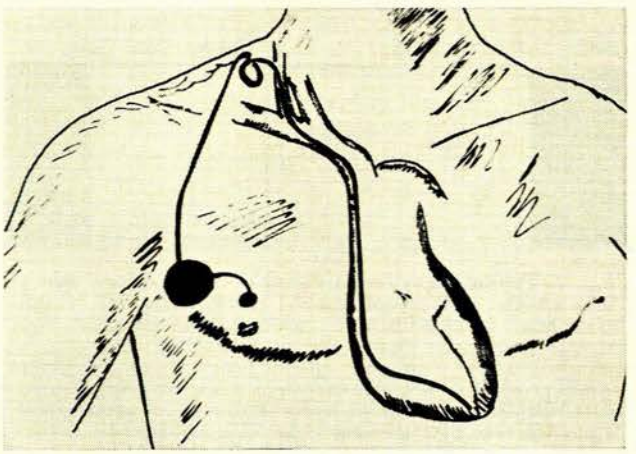

Fig. 6. A transvenous endocardial pacemaking wire-electrode with an implanted axillary generator and subcutaneous indifferent electrode.

TABLE I. CLINICAL FEATURES

No. of patients	13
Age range (years)	57–81
Mean	66
Associated diseases	
Carcinoma	
Face	1
Breast	1
Colon	1
Diverticulitis and colostomy	1
Myocardial infarction and multiple pathology	1
Paralysis agitans	1

a large pulse pressure from the increased stroke volume at the slow heart rate, irregular cannon waves in the neck, varying intensity of the first heart sound and independent atrial sounds. In 3 patients there was electrocardiographic evidence of previous intermittent complete heart block and bundle-

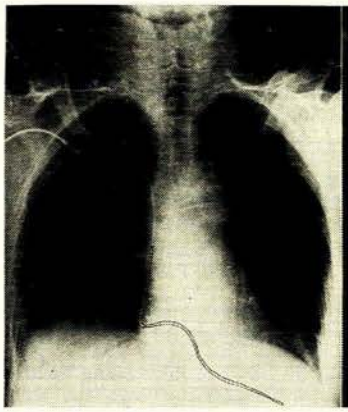

Fig. 7

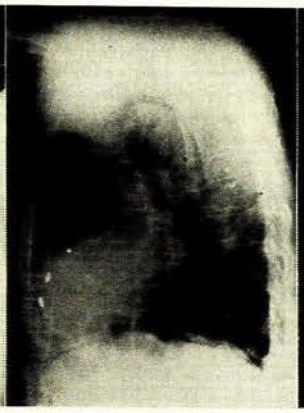

Fig. 8

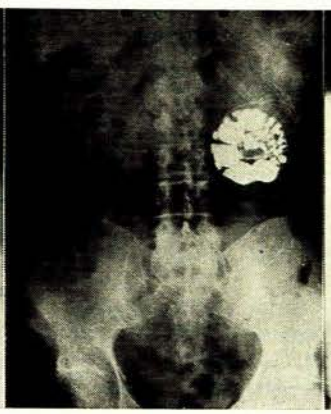

Fig. 9

Fig. 10

Fig. 7. Temporary transvenous pacing. The PA chest X-ray shows a temporary endocardial pacemaking wire passed along the right basilic vein, superior vena cava and right atrium to the apex of the right ventricle.
Fig. 8. Endocardial pacemaking electrodes. A pair of bipolar Elema electrodes sutured to the epicardium with pacemaking wires passing into the abdomen are seen on this lateral chest X-ray.
Fig. 9. The implanted abdominal generator. This is an AP abdominal X-ray of the patient in Fig. 8, showing the Elema 137 generator in the rectus sheath. The pacemaking wires pass upwards to the epicardial electrodes.
Fig. 10. Transvenous endocardial pacemaking wire electrode with implanted axillary generator. The X-ray shows the generator and indifferent electrode in the axilla. The endocardial pacemaking wire passes upwards behind the clavicle, lies in a loop at the root of the neck and then passes down the SVC and right atrium to the apex of the right ventricle.

branch block was often present, sometimes with double-branch block.

Emergency temporary pacemaking was required on 21 occasions, when the patients were seen initially, or subsequently, when a permanent pacemaker failed and a new unit was required (Fig. 7). A C51 or C52 unipolar or bipolar pacemaking electrode wire was passed from an antecubital vein in the right or left arm. Under radiographic control the platinum tip was positioned in contact with the endocardium near the apex of the right ventricle. The proximal end of the catheter was connected to an external pacemaker generator (Medtronic) with a variable rate and current control (Fig. 4). With this system it was possible to pace the heart for a period of up to a fortnight. Sepsis did not occur, but in one-fifth of the patients the catheter tip came loose and floated freely in the right ventricle, requiring repositioning. The pacemaker was used until a permanent unit was installed.

Three methods of permanent artificial pacing were used:

(*i*) An implanted abdominal generator with myocardial electrodes sutured on the epicardium

(*ii*) An implanted axillary generator with a transvenous endocardial pacemaking wire

(*iii*) An endocardial pacemaking wire used as an implanted epicardial system with an abdominal generator.

Initially 2 electrodes were sutured to the myocardium at thoracotomy (Figs. 5 and 8). The electrode wires were then brought down into the abdominal wall and the generator unit implanted in the rectus abdominus sheath behind the rectus muscle (Fig. 9). The fate and complications of the patients treated by this method are given in Table II. A Swedish Elema-Schonander generator unit was used (EM137 or 139) in 4 patients. In 3 the myocardial electrodes broke, 1 electrode suture was detached and in 1 case fibrosis around the electrodes produced a high-resistance system which prevented adequate pacing. The wires broke 1, 2 and 3 months after insertion (Table II). In one other patient, a St. George's abdominal unit with myocardial electrodes was inserted in London. After 9 months, fibrosis occurred around the lead and the pacemaker system failed. Spare myocardial leads were attached to the generator. Tissue fluid later entered the generator unit leading to failure after a further 3 months. A new St. George's abdominal generator was then inserted. This failed after a year and has now been replaced by an axillary unit inserted into the abdomen which was subsequently replaced by an Elema unit.

TABLE II. FATE AND COMPLICATIONS OF ABDOMINAL UNITS WITH STANDARD MYOCARDIAL ELECTRODES (St. George's Abdominal or Elema 137 or 139)

Number of patients		5
Number of generator units used:		
St. George's	3	
Elema	4	7
Still working		1
Died of Stokes-Adams attack		1
Broken or detached wires		4
Mean duration before wires broke		2 months
Generator failure		2
Mean duration of generator survival		1 year

As a result of repeated fracture of the myocardial wires, direct cardiac implantation was discarded and transvenous endocardial electrode wire pacing attempted in the subsequent patients until April 1965 (Figs. 6 and 10). Since September 1964, 14 axillary units have been inserted in 10 patients.

A solid unipolar C50 size 5 pacemaking wire electrode was used for pacing. This consists of a central stainless steel braided wire surrounded by a dacron and gum-elastic sleeve with a platinum tip. The procedure is performed under general anaesthesia by a combined medical and surgical team. The right external jugular vein is exposed in the neck and the catheter passed under fluoroscopic control until the tip is wedged among the papillary muscles and trabeculae at the apex of the right ventricle. An accurately calibrated (Corbin-Farnsworth), variable voltage, external pacemaker unit is used to measure the excitation threshold voltage. This indicates the minimum voltage required to initiate a ventricular contraction. If this exceeds 0·5 volts the position of the catheter tip is altered until a suitable site is found. A second skin incision is made in the axilla and a pocket created for the generator unit. The catheter is looped in the neck to provide a small accessible portion for repositioning, if required, and the proximal end drawn into the axillary pocket through a tunnel behind the clavicle. The generator and electrode are connected while a second indifferent electrode connects the generator to the subcutaneous tissue. The incisions are then closed. When the unit was re-explored later the generator lay in a well-developed capsule or pocket.

The complications and fate of the 14 units are summarized in Table III. Pacemaking failed and the electrode tip had to

TABLE III. FATE AND COMPLICATIONS OF IMPLANTED AXILLARY UNITS (St. George's A or X-12, Elema—2)

Number of patients	10
Died	2
Alive	8
Number of generator units used	14
Generator failure	5
Broken catheter or indifferent electrode	2
Catheter repositioning	10
Still working	6
Mean duration of implantation	3 months
Duration of longest satisfactory function	9 months

be repositioned on 10 occasions. Definite myocardial perforation occurred twice. The remaining episodes of pacemaking failure occurred as a result of increased endocardial resistance requiring a larger pacemaking voltage, or intermittent contact between electrode tip and endocardium. Five generator units have failed and have been replaced. In 4, this was associated with one or more episodes of electrode tip malposition, suggesting that premature generator failure was a result of additional power drain on the batteries. In the fifth, premature generator failure occurred after 4 months of adequate pacing. The threshold for pacing was still normal when the generator was removed, indicating that the power output of the St. George's axillary unit was inadequate for long-term pacing. We have also used two Elema abdominal units inserted into the axilla in association with an endocardial wire electrode. One wire broke in the neck and at the tip after 3 months, but when the Elema generator was removed because of a cracked

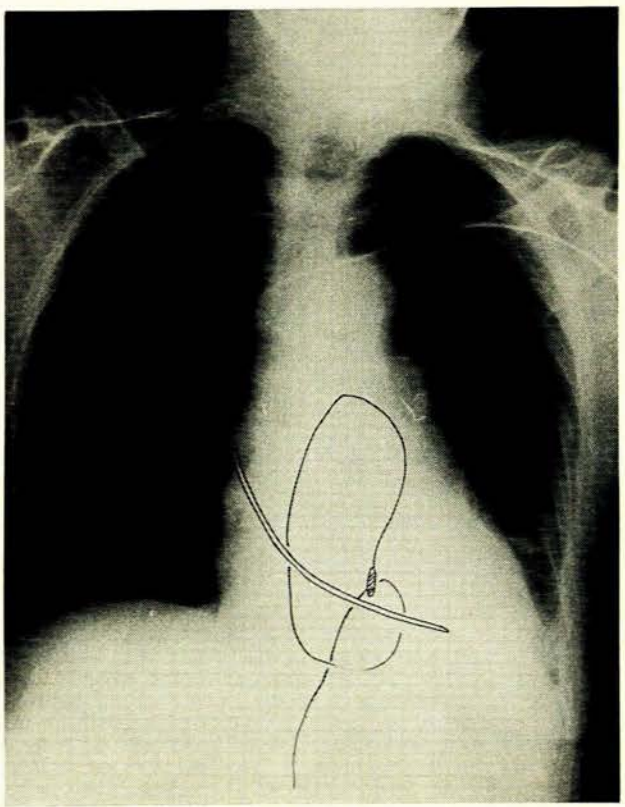

Fig. 11. Modified epicardial electrode. This X-ray shows the Elema endocardial pacemaking wire electrode which is sutured to the epicardium, looped in the pericardial cavity and then passed to an abdominal generator. A temporary transvenous pacemaking wire electrode is also in position, with the tip passing to the apex of the right ventricle.

casing and tested, the output was unchanged. Axillary units are still working in 6 patients with a mean duration of 3 months.

With the passage of time it became evident that repeated electrode-tip malposition and the inadequate energy capacity of the axillary units were disadvantages of an otherwise simple technique. An alternative technique of epicardial pacing was evolved by one of us (C.N.B.). A thoracotomy was performed and Elema endocardial electrode wires were implanted in the myocardium and anchored in place with teflon sutures (Fig. 11). A loop of wire was left free in the pericardial cavity to reduce deformation stresses and then led to the Elema generator inserted in the abdomen. One wire detached shortly after insertion and the other patient developed a large pleural effusion after implantation.

We are therefore using the transvenous endocardial wire electrode once more, since this method is so much simpler, and also kinder to an elderly patient. The Elema EM139 generator has a longer pacemaking life, and is now being inserted in the axilla or rectus sheath in association with the transvenous endocardial electrode.

DISCUSSION

Our experience with long-term electrical pacing has been small, but in spite of many problems the results have been encouraging and rewarding.

Temporary Transvenous Electrode Pacing

This has presented few difficulties. We did not observe the high incidence of sepsis that has been reported.[28] One patient who had not been included in the series of long-term pacemaking, however, developed a staphylococcal septicaemia from a diffuse infective eczema after a short-term pacing only.

Repeated electrode tip malposition shortly after insertion was encountered frequently. Presumably, when the arm was moved vigorously the catheter tip was dislodged from its secure position between the trabeculae of the right ventricle, floated free in the ventricular cavity and paced intermittently. The fault was corrected by repositioning the catheter tip.

At present, temporary pacemaking is used only in emergency life-threatening situations for repeated Stokes-Adams attacks. It is also inserted before permanent pacemaking to safeguard the patient under anaesthesia until the permanent unit is working.

Permanent Pacemaking with Implantable Generator Units

Long-term permanent pacing of the heart is a formidable major undertaking and we have been guided by the extensive American and British experience.[11-15,19-22]

Implantable Epicardial Electrodes

The satisfactory earlier reports with the epicardial electrode system prompted us to start with a system of epicardial stimulation using an Elema-Schonander generator.[11-15,19,29,30,32] There are several problems which occur with epicardial pacing. There is the possibility of electrode fracture or instability. The heart beating at 70 times per minute produces a constant, recurrent deformation stress in an implanted system with 2 fixed ends. The Elema electrodes consist of a platinum myocardial electrode with 600-mm. long electrode wires made of flexible, fatigue-resistant stainless steel insulated with polyethylene. In spite of the manufacturer's claim of fatigue-resistance, fracture or dislocation of the wires occurred in 4 patients. Other systems available at present include the St. George's electrode which consists of a triple spiral wire of stainless steel with a platinum tip; and the Chardack platinum-coil electrode

plate with a small platinum iridium core and a solid silicone rubber sleeve for insulation.[12,32] The use of a single continuous structure (coil) eliminates all welded or soldered junctions of dissimilar metals, which may become a source of flaws during the manufacturing process. Moreover, junctions of dissimilar metal may also corrode when exposed to tissue fluids. Our electrodes have broken or the myocardial attachment loosened. This is not surprising since it is difficult to suture the electrode to the soft mushy myocardium without too many sutures which may produce necrosis.

In one patient the myocardial electrodes were surrounded by extensive fibrosis and the threshold voltage required for pacing increased. Many factors are known to govern electrode performance after implantation:[32] accumulation of seropurulent fluid within the electrode tracks, surrounding fibrosis, corrosion of the electrodes themselves and mechanical trauma to the myocardium. Moreover, the power requirement for epicardial pacing is higher than an endocardial system so that a larger generator unit is required.

Davies and Siddons[22] have stopped using this method since sepsis was common and abdominal sinuses occurred. Sepsis has not been a problem in Cape Town.

Epicardial pacing requires open thoracotomy and the older patient is at risk from postoperative chest complications. In view of this and the high incidence of wire fracture, we have preferred transvenous pacing.

Transvenous Endocardial Wire Electrode Pacing

With this technique the patient is spared thoracotomy and major surgery. If required, the electrode position can be changed with a minor surgical procedure and the danger of pericardial and pleural infection is eliminated.[20]

On the other hand, loss of electrical contact between the platinum tip and the myocardium has been a major problem. Once contact is lost the patient either paces intermittently or reverts to idioventricular rhythm, with the possibility of Stokes-Adams attacks and intermittent ventricular fibrillation. Catheter-tip malposition usually occurred during the first 48 hours. If the tip was wedged insecurely, it was displaced by movement of the neck, and floated freely in the ventricular cavity. Pacing was intermittent or ceased. Siddons and Davies[20] have also shown that once contact is established between the pacemaker and endocardium, the minimum voltage required for stimulation (threshold voltage) increased nearly tenfold during the first 3 weeks of pacing. Moreover, the bare platinum may become covered with thrombus, interfering with pacing.[33] We have not observed this, since the endocardial electrode is always used as a cathode.

Perforation of the heart also occurs and we had at least 2 proven and 2 possible episodes. Once the catheter tip lies in the pericardial cavity electrical contact is lost. The myocardium retracts on the catheter itself and haemorrhage does not occur.

Transvenous wires have the advantage of simplicity, but the problem of intracardiac stability still requires solution. We hope that with more experience it will be possible to position the electrode tip in such a way that these complications do not occur.

Mechanical Failures

Electrode wire fracture. One electrode wire broke in a younger, more active Coloured female. It cracked in the neck where it was subject to repeated stresses from neck movement, and also at the tip where it was embedded in the myocardium (Fig. 11).[21,22]

Pacemaker generator units. We have used implantable generators only and have no experience of the large high-powered external generators which employ electromagnetic or radiofrequency induction to trigger an implanted wire system.

Three different implantable generator units were used: the St. George's abdominal or axillary (Models A or X) and Elema-Schonander abdominal units (Model EM137 or 139). These contain a blocking oscillator-circuit powered by mercury-cell batteries providing an impulse of fixed time duration, amplitude and rate. Mercury cells are small and light with a long shelf life and high power rating. Each unit has an estimated life of 3 - 5 years, but once the energy requirements of the pacing circuit increase, the power drain soon exhausts the batteries. We have had frequent early generator failures after implanting a St. George's unit. A careful study of the data of Davies and Siddons[22] shows that at present the longest generator life is 1½ years and the majority fail after 1 year.

Apart from battery exhaustion, faults may occur in the electronic components (transistors, transformers and resistors) and although high specification requirements and length of life are laid down by the manufacturers, component failure occurred, particularly in the earlier models used in England.[20] The entire unit is cast in epoxy-resin and the St. George's unit is also covered in silicone rubber. These substances reduce the tissue reaction to the implanted foreign material and are impermeable to destruction by tissue fluids. However, faults in the casing occur and in one patient tissue fluid entered the generator and led to failure.

Connection faults. The bare proximal end of the electrode wires are attached to the terminals of the generator. The joint must make good electrical contact but should retain watertight insulation, since seepage of tissue fluid into the pacemaker unit may interfere with function.[22] The wires are held in place by 2 nylon screws and protective silicone grease is rammed into the crevices by the screw.

ADVANTAGES OF THE USE OF PACEMAKERS

Clinical Improvement in the Patients

After considering the difficulties inherent in implanting a battery and malleable electrode wire system, one may enquire whether such a procedure is justifiable or beneficial.

All the patients were active individuals and valuable members of society with lucid intellects, although one was an octogenarian. Before insertion of the pacemaker, they were disabled, dyspnoeic, weak and terrified by frequent Stokes-Adams attacks with electrocardiographic episodes of asystole or ventricular fibrillation. After insertion of the pacemaker, their mode of life changed, they were able to walk in comfort without weakness, tiredness or shortness of breath and the frequent Stokes-Adams attacks disappeared. In each instance artificial pacemaking made the patient happier and more comfortable.

Patients who were maintained on long-term pacing at a rate of 70 per minute soon detected a fall in rate. In 3 patients generator failure was associated with a gradual reduction of heart rate, falling to 50 beats per minute before a new permanent unit could be obtained for insertion. The patients themselves detected the fall in heart rate, felt weak and tired and were unable to undertake their normal activities, and requested that a new unit be inserted.

Physiological Improvement after Insertion of the Pacemaker

The clinical well-being which occurs with artificial pacemaking is a result of improved myocardial performance.[32,34-37] When in idioventricular rhythm, a low cardiac output is maintained by a high stroke volume which cannot increase further on exercise. Since the cardiac output is subnormal during exertion the subjects are weak and tired and cannot undertake exercise. Cardiac failure is common. When paced at rates of 60 - 70/min. the cardiac output increases and objective improvement occurs in exercise capacity. In a heart deprived of the atrial booster pump, diastolic filling is impaired at rates of more than 70/min.[38,39] and, under these circumstances, the P-wave synchronized pacemaker will prove of value.[35] Pacemaking at a subnormal rate is useful in a patient who has learnt to live at a heart rate of 40/min. and the slightly subnormal rate of 70/min. reduces the energy requirements of the heart itself.[32] At higher rates too myocardial failure may occur, since in these patients with fibrosis of the bundle, generalized myocardial fibrosis and coronary artery disease may also be present. Thus, when the heart rate is increased too much, the cardiac output falls instead of increasing.

Indications for Implanting Cardiac Pacemakers

We have not implanted pacemakers in all patients with complete heart block. Such patients are kept under surveillance and treated with long-acting sympathomimetic drugs (long-acting isoprenaline, up to 600 mg. 2-hourly, or ephedrine ½ gr. *t.d.s.*). Implanted pacemakers are reserved for:

1. Disabling and frightening episodes of unconsciousness related to ventricular standstill or tachycardia with heart block (Stokes-Adams attacks) and the possibility of sudden death in patients with one or more of these attacks.
2. Symptoms of heart failure, or inadequate cerebral perfusion as a result of the very slow heart rate.[40]

Associated Clinical Features

The high incidence of carcinoma or other dual pathology is a reflection of the age range of these patients. One patient made a complete recovery after resection of a localized carcinoma of the colon. These lesions are not a contraindication if pacemaking is required.

Aetiology

The aetiology of complete heart block is obscure. Lev and others have invoked patchy fibrosis of the left side of the cardiac skeleton as the cause of the lesion.[41-43] They feel that the left ventricle, mitral and aortic valve, and aorta move on the fixed fibrous skeleton and that the extensive fibrosis seen at autopsy is a natural result of the deformation stresses in this important region. In 3 of our patients there was intermittent heart block or bundle-branch block before complete heart block occurred. Presumably this was due to patchy fibrosis before the entire bundle was involved in the process.

Artificial pacing is not indicated in patients with congenital heart block since they lead a normal life and have a normal exercise tolerance in spite of the slow heart rate.[44] The rarer causes of congenital heart block, diphtheritic, gummatous, traumatic and post-surgical block have not occurred during the period of this survey.

Artificial Pacemaking in the Future

As the life expectancy of the population increases, the incidence of complete heart block will rise. Conservative estimates indicate that in the USA there may be as many patients with complete heart block as those with congenital heart disease. Moreover, development in electronics and the production of fatigue- and tissue-resistant materials promise to simplify the engineering problems of pacemaking.

CONCLUSIONS

At present there is no method of artificial pacing which is fault-free or completely reliable.

We have used 3 methods of pacing. Both epicardial systems have failed because of electrode wire fracture or inability to fix the wire securely to the myocardium without producing extensive and undesirable surrounding fibrosis.

The endocardial system has the advantage of simplicity. The problem of generator failure has in part been solved by the use of a more powerful generator unit. We also feel that with more experience electrode-tip malposition will be less common and the results more satisfactory. Until a more reliable technique of attaching epicardial electrodes becomes available we shall continue to use the transvenous technique.

In spite of these difficulties, the poor prognosis, and the poor quality of life that the patients live without pacing, have induced us to persist and thereby obtain a satisfactory method of long-term pacing.

Since so many variable factors contribute towards failure or success, treatment should be undertaken only in centres with long-term experience of the problem ; apparent initial successes are frequently disappointing after longer periods of surveillance.

It is also important that the patients understand the nature of their disease, are aware of the possibility of pacemaker failure and know the correct emergency management. Moreover, the patient and general practitioner should maintain close liaison with the specialist centres so that defects can be rectified as soon as possible.

SUMMARY

Permanent artificial pacemaking has been undertaken in 13 patients with complete heart block for repeated Stokes-Adams attacks or intractable cardiac failure.

Emergency temporary pacemaking was used on 21 occasions. The only difficulty experienced was dislocation of the catheter tip. Permanent pacing was used in all these patients. Nine abdominal units with epicardial electrodes were used. The myocardial electrodes fractured or the sutures broke in 4. One patient died when the electrode was detached from the heart. Fourteen axillary units were used with a transvenous electrode pacemaking wire. Two patients died of unrelated causes and 5 units are still working. Generator failure occurred in 5 and in

1 the catheter tip fractured. The catheter tip was repositioned on 10 occasions.

Long-term pacemaking has produced technical problems, but the results have been both satisfactory and rewarding.

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