Cardiac pacing in children

D E WARD, M SIGNY, P OLDERSHAW, S JONES, AND E A SHINEBOURNE

Department of Cardiology and Department of Paediatrics, Brompton Hospital, London

SUMMARY Twenty patients aged between 12 months and 13 years underwent permanent pacemaker implantation. The main indication for pacing was post-surgical atrioventricular block. The complication rate was high and related mainly to infections and lead system problems. The use of small multiprogrammable pacemakers is expected to reduce the reoperation rate for system malfunction and elective replacement. Newer methods of electrode insertion and active fixation devices in smaller diameter leads make endocardial pacing a practical alternative to epicardial pacing in the larger child who did not require a pacing system at the time of surgery.

Implantation of permanent cardiac pacemakers in infants and children is often complicated by problems such as infection or unreliability of the pacing system. In this report we review our experience of pacemaker implantation in 20 children from 1970 to 1981, with particular emphasis on these aspects.

Patients and materials

Of 20 patients aged between 1 and 13 (mean 7½) years at the time of initial pacemaker implantation, 5 patients had symptomatic congenital bradycardia and 15 had arrhythmias after surgical procedures for congenital cardiac defects (Table 1). Complete atrioventricular (AV) block after surgery was the largest single indication for pacing. One patient developed sinus node dysfunction after total correction of Fallot's tetralogy. Details of the type of pacemaker and electrode used at first operation for implantation are shown in Table 2. Lithium-powered units have been used since 1975 and during the last 2 years we have implanted programmable (Teletronics 171) or multiprogrammable (Medtronic 5985) pacemakers. Seventeen patients had epicardial systems at initial operation. Of these, 15 had right ventricular epicardial systems, one a left ventricular epicardial system, and one child had an atrial triggered ventricular pacemaker. Three children, aged 10, 10, and 13 years, each without associated cardiac defects received endocardial systems (2 ventricular, 1 atrial). Two had juvenile sinuatrial disease and one had congenital AV block. In these patients an active fixation electrode was implanted (Helifix (Vitatron) in one patient, and Medtronic 6959 in two) (Fig. 1), and the pacemaker was sited in the left prepectoral area. Pacemakers attached to epicardial electrodes were sited in the

anterior abdominal wall in 16 patients. In one patient, a 1-year-old 9.2-kg girl, a programmable pacemaker was implanted in the left pleural cavity

Fig. 1 X-ray film showing Medtronic 6959 electrode in right atrium in a 10-year-old child with sinuatrial disease.

Table 1 Clinical data and indications for pacing

Indications	Number	AV block	Sinus node dysfunction
Post surgical			
Complete transposition of great arteries	2	2	
Fallot's tetralogy	3	2	1
Partial AV canal and related defects	5	5	
Ventricular septal defects	4	4	
Isolated mitral regurgitation	1	1	
Non-surgical			
Partial AV canal	1	1	
Ventricular septal defect	1	1	
Normal heart	3	1	2

Table 2 Initial pacemaker type

	Lithium battery	Zinc mercury battery
Ventricular demand (VVI)	10 (3 programmable)	7
Ventricular fixed rate (VOO)	—	1
Ventricular, atrial triggered (VAT)	—	1
Atrial demand (AAI)	1 (1 programmable)	—

Table 3 Complications and indications for reoperation

	Number	
	Of reoperations	Of patients
End of life	7	5
Complications	16	7
Infections, 5 reoperations in 4 patients		
Threshold rise, 7 reoperations in 6 patients		
Fractured lead, 3 reoperations in 3 patients		
Migration of unit, 1 reoperation in 1 patient		

Median electrode survival = 43.5 months (all leads).

and could be programmed *in situ* without difficulty.

In patients in whom reoperations were required the maximum survival time of the initial pacing system was 56 months. Altogether 23 reoperations were necessary in 12 children (Table 3).

Mean survival time of the first pacing system was 24 ± 19.5 months varying from 0.3 to 56. Five children have required one reoperation, 4 children have had two, 2 have had three, and one child has required four reoperations. The mean time between operations was 21.5 ± 17.2 months. Sixteen reoperations in 7 children were for complications (Table 3) the most common of which was an increase in stimulation threshold resulting in intermittent or total failure to capture. Threshold increases occurred 0.3 to 34 months after electrode implantation. In 5

of the 7 reoperations for high threshold the electrode was of the epicardial screw-in type (Medtronic 6917 and 6917-A). Infections required revision of the pacing system on five occasions but on only three was the electrode changed. In one child merely resiting the pacemaker and failing to change the electrode after infection resulted in a chronic infection that eventually required complete revision 15 months later. Partial extrusion of the pacemaker was associated with the infection in two instances. Lead fracture was documented on three occasions, all longer than 2 years after implantation. In one patient, the pacemaker migrated from the rectus muscle to the pelvic cavity and required resiting.

The pacing electrode was changed 15 times in 9 children (Table 4). The median electrode survival was 43.5 months. In 9 children the original electrode is still functioning after follow-up from 6 to 136 months. In one patient a high threshold on an endocardial lead was discovered and a previously (implanted) left ventricular epicardial lead was re-exposed and testing revealed a satisfactory threshold. The pacemaker was reattached to this lead, but the patient died suddenly 9 months later. Replacement endocardial electrodes were implanted in 10 instances (endocardial screw in 2 patients, tined leads 3 patients, flanged 2 patients, unknown 3 patients). Fig. 2 shows an endocardial screw-in electrode in a patient who had undergone a previous Rastelli procedure and implantation of an epicardial pacing system.

The pulse generator was changed on 16 occasions in 10 children. Elective change for end of life was undertaken 7 times in 5 children. The mean lifetime of these units was 30.3 ± 17.6 months. Two were

Table 4 Electrode changes

Reason for reoperation	Old electrode			New electrode		
	Site	Type	Age at revision (months)	Site	Type	Time since implant (months)
End of life of unit n=2	RVEPI	(SI)	52	RVEND	(SI)	2
	RVEPI	(SI)	46	RVEND	(SI)	7
Infection n=3	RVEND	(T)	9	RVEND	(Not known)	8
	RVEPI	(IM)	11	RVEND	(F)	L
	RVEND	(Not known)	16	RVEND	(T)	12
Threshold rise n=7	RVEPI	(SI)	34	RVEPI	(SI)	*
	RVEND	(DH)	0.3	RVEND	(T)	*
	RVEPI	(SI)	2	RVEND	(Not known)	29
	RVEPI	(SI)	17	RVEPI	(SI)	3 died
	LVEPI	(SI)	2	RVEND	(F)	*
	RVEND	(F)	4	LVEPI	(SI)	9 died
Lead fracture n=3	RVEPI	(SI)	26	RVEND	(Not known)	*
	RVEPI	(SI)	52	RVEND	(T)	9
	RVEPI	(IM)	43	RVEPI	(SI)	*
	RVEPI	(SI)	28	RVEPI	(SI)	*

RV=right ventricle, LV=left ventricle, EPI=epicardial lead, END=endocardial lead, SI=screw-in electrode, T=tined electrode, IM=intra-mutual electrode, DH=double helix electrode, F=flanged, L=lost to follow-up, *new electrode subsequently no longer used.

FIG. 2 X-ray film showing left ventricular endocardial screw in electrode (Medtronic 6959) in a patient who had undergone a Rastelli procedure for transposition of the great arteries.

lithium powered and 5 were mercury-zinc powered. In 9 other instances the generator was replaced prematurely at the time of reoperation for a complication (infection 4, fractured lead 2, high threshold 2, migration 1).

Of the 16 generator changes, lithium-powered units were used as replacements in 14 (VV1 in 9, V00 in 5) instances. Multiprogrammable pacemakers (Medtronic SX) were implanted at 5 reoperations involving a generator change.

Follow-up has ranged from 6 months to 11 years (mean 3.4 ± 3.0 years) with a total of 69 patient years. There have been 4 deaths of which 3 were sudden and may have been caused by pacemaker failure. One patient died with endocarditis but without evidence of an infected pacing system.

Discussion

In common with other published series of pacemaker implantation in children, the most frequent indication was postoperative AV block. Of a total of 577 paced children from thirteen series¹⁻¹³ recently reviewed by Young¹⁴ and four additional series¹⁵⁻¹⁷ (including these data) 354 (61.4%) required pacing for surgically induced AV block (Table 5). The incidence

Table 5 Summary of indications for pacing in 577 children reported in 18 series (references 1-17 plus this report)

	AV block	Sinoatrial disease	Total
Surgical	354	19	373
Non-surgical	167	37	204

92 deaths which were pacemaker-related in 37.

of this problem has been greatly reduced by intra-operative mapping¹⁸⁻²⁰ and a better understanding of the surgical anatomy of the conduction system in congenital heart disease. However, persistent post-surgical AV block remains an appreciable complication of repair of complex defects.¹⁹

The need for pacing in this group of patients has been questioned²¹⁻²³ and it was suggested that the outlook for postoperative AV block was favourable with the risks of conservative therapy outweighing the problems of chronic pacing. Subsequent experience however, suggests that the mortality associated with postoperative AV block is considerably reduced by permanent pacing^{1 24} even if sinus rhythm resumes postoperatively.²⁴ Conversely, Nissen *et al.*⁵ reported 19 patients who had had transiently perioperative AV block who were not paced in the long term and have been followed up for longer than 57 months without mortality. Nevertheless, late onset complete AV block²⁵ or intraventricular conduction disturbance²⁶ is well known. Izukawa *et al.*²⁷ suggests that the prognosis of transiently perioperative AV block with associated bifascicular block is worse than that of either abnormality occurring alone.

The question of prophylactic pacing for persistent intraventricular conduction defects after surgery is a subject of continuing debate. In the data reviewed by Krongrad²⁴ late onset complete AV block or sudden death was much more common in patients who had had transiently perioperative complete AV block in addition to right bundle branch block and left axis deviation. Wolff *et al.*²⁸ found a significant incidence of late onset complete AV block or sudden death in patients with post-operative bifascicular block compared with patients without this pattern on the electrocardiogram (ECG). In contrast others^{29 30} suggest that this ECG pattern is benign. The reason for these disparate results may be a difference in surgical technique and type of injury to the conduction system.^{31 32} It has been suggested that a prolonged HV interval in patients with bifascicular block may identify patients at risk of developing sustained complete AV block or sudden death.^{26 27 29 31 33 34} However, in the series of Godman *et al.*²⁶ all patients with bifascicular block and prolonged HV intervals had transiently perioperative complete AV block, which may be a more reliable predictor of late morbidity.²⁷ The value of HV interval measurement in these patients is not known.³³

Although postoperative sinus node dysfunction is rare after surgical repair of congenital defects it may occur after Mustard's operation or other procedures that damage the sinus node.^{35 36} In one patient in this series, sinoatrial dysfunction occurred

after total correction of Fallot's tetralogy. This unusual complication has been previously documented.^{37 38} Only 3.2% of 577 implants have been paced for postoperative sinus node disorder (Table 5). Isolated sinoatrial dysfunction with failure of the junctional escape mechanism is rare in children^{39 40} but may be a cause of sudden death in them.^{39 41} Both our cases had experienced near syncope or dizziness and had documented asystolic pauses of over 3½ seconds.

Although rare, symptomatic congenital AV block is also an indication for permanent pacing whether or not there are associated cardiac defects.⁴¹ If coexisting abnormalities require surgical repair it is probably prudent to insert a permanent pacing system at the time of operation.⁴² In general, asymptomatic AV block in the presence of a reliable junctional pacemaker (as assessed by prolonged ECG monitoring and electrophysiological studies) does not require pacing. However, follow-up is advisable because symptoms may appear later in life. Syncopal spells and dizziness are indications for pacing even if bradycardia cannot be shown to be causally related to these symptoms. Heart failure and limited exercise capacity caused or exacerbated by persistent bradycardia may also be considered indications for long-term pacing in carefully chosen patients.

The incidence of complications in the present series is high but similar to that previously reported.^{1-13 15-17} Problems related to the lead system were the most common major complications requiring reoperation. Late threshold rises (the largest single problem) tend to be higher with epicardial than endocardial electrodes^{43 44} and some series⁴³⁻⁴⁵ have suggested that the sutureless screw-in electrode (Medtronic 6917 and 6917A) results in higher thresholds than other epicardial leads. In this series 5 of 7 reoperations for high threshold were in children with epicardial screw-in leads. Epicardial electrodes have also been more prone to conductor fracture and other primary electrode problems than are endocardial leads.^{41 46 47} Our own experience in adults⁴⁸ would certainly support this view. The high incidence of lead system malfunction in children⁵ may be caused by the combined effects of growth, use of epicardial electrodes, and unrecognised electrode damage at the time of reoperation.

Infection and erosion also account for a large proportion of complications^{2 49} and in one series² 26% of reoperations were for this problem.

It has been suggested that abdominal placement of the pacemaker is associated with a lower incidence of infection and extrusion.³ However, 4 of 5 infected nits in this series were implanted deep to the rectus

abdominis. In two instances the pacemaker was of a fairly large volume (Teletronics 159, Cordis Stanicor) which probably contributed to the development of infection. Intrapleural implantation has been recommended in an attempt to reduce the risk of complications caused by the size of the pulse generator.⁵⁰ However, with the small pacemakers currently available, we believe that intrapleural placement should be considered only in very small children or in those whose pacing system requires protection. Pacemaker pocket infection should be treated promptly by total explantation of the system.⁵¹ Failure to do this may result in chronic recurrence of infection and the need for reoperation (as in one of our cases) or septicæmia.⁵²

Pacemaker related deaths occurred in 37 of 577 patients and represented over one-third of all deaths (Table 5). One of the deaths was of a patient who had undergone revision of the system one year earlier at which time a previously implanted left ventricular epicardial lead was used because it appeared reliable. This approach is inadvisable because of the risk of recurrence of the initial electrode problem.

Transvenous electrode placement in infants and children^{53 54} has received little attention because of possible technical difficulties with this method and the common need to implant the pacemaker at the time of surgery. The major limitations of the transvenous method are caused by difficulties in inserting the electrode into small veins, occasional problems in locating the electrode in a malformed heart, and the high displacement rate of endocardial electrodes. However, many of these problems may be surmounted with newer techniques of electrode insertion and more reliable electrodes. Direct subclavian puncture is now an established method of electrode insertion in adults⁵⁵ and has been used in infants.⁵⁶ This method was successfully used in two of our children. The development of reliable active fixation electrodes is an important advance in endocardial pacing. The Medtronic 6957 screw-in electrode has been very successful in adults⁵⁷ with a low complication rate, and there are limited long-term studies of endocardial screw-in electrodes in infants⁵⁸ and children⁵⁹. We have successfully used the Medtronic 6957 lead and the 6959 lead⁶⁰ in 4 patients even in the presence of distorted cardiac anatomy (Fig. 2). The active fixation device allows a large redundant loop without an increased risk of displacement. The increased loop size is taken up as the child grows, in the hope of reducing the frequency of revision procedures. Another advantage of this type of electrode is the ability to screw in the tip at myocardial sites which have previously been unsuitable because of electrode instability. In one

of our patients the electrode was passed via a left superior vena cava.⁶¹ We have also implanted the 6959 model in the atrium of one child with sinus-atrial disorder.

The incidence of lead fractures is expected to decline with the introduction of more resilient electrode materials⁶² and chronic threshold rises will be diminished by the use of less reactive and non-polarised electrode tips.⁶³ These advances should reduce the 'technical' complication rate of endocardial systems.

In most of our patients, we have implanted ventricular demand pacemakers (VV1) and we see no indication for the use of fixed rate (VOO) devices other than the advantage of the small size in neonates. However, modern multiprogrammable units are of comparable small size and therefore preferable. There is little experience of so-called 'physiological' pacing modes in children. Furman and Young⁶⁴ failed to observe any change in clinical status when VAT units (atrial triggered, ventricular pacemakers) were exchanged for ventricular pacemakers. Nevertheless, in some patients, maintenance of AV synchrony with or without ventricular pacing may be appropriate.⁶⁴

Programmable and multiprogrammable pacemakers are now available in small sizes. The ability to adjust non-invasively the characteristics of these units may greatly reduce the rate of reoperation for system malfunction.⁶⁵ In this respect, programmability of output and sensitivity are at least as important as rate in paced children. For these reasons we recommend a multiprogrammable unit in all children who require pacing.

Conclusion

The majority of children who need pacemakers have congenital heart disease and most of these require pacing after surgery.

Most of the problems of long-term pacing in children are related to pacemaker size and unreliability of the lead system. Small, multiprogrammable pacemakers and more reliable electrodes are expected to reduce the incidence of problems. The advantages and ease of transvenous pacing make this method an attractive alternative to trans-thoracic pacing in the larger child who does not require implantation at surgery.

If feasible and appropriate we prefer to implant new endocardial systems in patients who require revision of existing epicardial systems for any reason.

References

- Hofschire P J, Nicoloff D M, Moller J H. Post operative complete heart block in 64 children treated with and without cardiac pacing. *Am J Cardiol* 1977; **39**: 559-62.
- Williams W G, Izukawa T, Trusler G A, Smith J M. Experience with permanent cardiac pacing in paediatrics. In: Meere C, ed. *Proceedings of the Sixth World Symposium on Cardiac Pacing, Montreal, Canada 1979*. Montreal: Pacesymp, 1979: chapter 23-7.
- Van Heeckeren D W, Borkat G, Clayman J A, Horrigan T P, Ankeney J L. Pacemaking in children. In: Meere C, ed. *Proceedings of the Sixth World Symposium on Cardiac Pacing, Montreal, Canada 1979*. Montreal: Pacesymp, 1979: chapter 23-4.
- Hayward R P, Somerville J, Rickards A F. Problems of permanent pacing in children. In: Meere C, ed. *Proceedings of the Sixth World Symposium on Cardiac Pacing, Montreal, Canada 1979*. Montreal: Pacesymp, 1979: chapter 23-34.
- Nissen R G, Holmes D R, Maloney J D, Feldt R H, Danielson G K. Experience with permanent cardiac pacemakers in congenital heart disease. In: Meere C, ed. *Proceedings of the Sixth World Symposium on Cardiac Pacing, Montreal, Canada 1979*. Montreal: Pacesymp, 1979: chapter 23-1.
- Shearin R P, Fleming W H. Fourteen years of implanted pacemakers in children. *Ann Thorac Surg* 1978; **25**: 144-7.
- Whitman V, Berman W, Jr, Tyers G F O. Pacemakers in young patients: 1977. *J Pediatr* 1978; **92**: 722-4.
- Gamble W J, Owens J P. Pacemaker therapy for conduction defects in the paediatric population. In: Roberts N K, Gelband H, eds. *Cardiac arrhythmias in the neonate, infant, and child*. New York: Appleton-Century-Crofts, 1977: 469.
- Benrey J, Gillette P C, Nasrallah A T, Hallman G L. Permanent pacemaker implantation in infants, children, and adolescents. Long term follow up. *Circulation* 1976; **53**: 245-8.
- Marco J D, Codd J E, Barner H B, Czerwinski B S, Kaiser G C. Implantable pacemakers in children. *Arch Surg* 1975; **110**: 880-3.
- Stanton R E, Lindesmith G G, Meyer B W. Pacemaker therapy in children with complete heart block. *Am J Dis Child* 1975; **129**: 484-7.
- Griffiths S P, Hayes C J, Bowman F O, Jr, Gersony W M. Long term follow up of two infants with an implanted cardiac pacemaker. *Am J Cardiol* 1975; **36**: 921-4.
- Daicoff G R, Aslami A, Tobias J A, Miller B L. Management of postoperative complete heart block in infants and children. *Chest* 1974; **66**: 639-41.
- Young D. Permanent pacemaker implantation in children: current status and future considerations. *PACE* 1981; **4**: 61-7.
- Hagl S, Meisner H, Sebering F. Permanent pacing in infants (abstract). *PACE* 1980; **3**: A373.
- Weber H, Eigster G, Wesselhoeft H, Ruschewski W, de Vivie E R. A 17 year survey of permanent pacing in infants and children (abstract). *PACE* 1981; **4**: No 3, A26.
- Lunati M, Bruno A M, Sozzi G, Gentili D, Gadaleta G. Permanent cardiac pacing in paediatrics (abstract). *PACE* 1981; **4**: No 3, A57.
- Krongrad E, Malm J R, Bowman F O, Jr, Hoffman B F, Kaiser G A, Waldo A L. Electrophysiological delineation of the specialized atrioventricular conduction system in patients with congenital heart disease. I. Delineation of the His bundle proximal to the membranous septum. *J Thorac Cardiovasc Surg* 1974; **67**: 875-82.
- Dick M, Norwood W I, Chipman C, Casteneda A R. Intraoperative recording of specialized atrioventricular conduction tissue electrograms in 47 patients. *Circulation* 1979; **59**: 150-60.

- 20 Lincoln C, Butler P, Logan-Sinclair R, Anderson R H. A cardiac conduction monitor and probe for intra-operative identification of conduction tissue. *Br Heart J* 1979; **42**: 339-44.
- 21 Murphy D A, Tynan M, Graham G R, Bonham-Carter R E. Prognosis of complete atrioventricular dissociation in children after open heart surgery. *Lancet* 1970; **i**: 750-2.
- 22 Hurwitz R, Riemenschneider T A, Moss A J. Chronic postoperative heart block in children. *Am J Cardiol* 1968; **21**: 185-9.
- 23 Squarcia U, Merideth J, McGoon D C, Weidman W H. Prognosis of transient atrioventricular conduction disturbances complicating open heart surgery for congenital heart defects. *Am J Cardiol* 1971; **28**: 648-52.
- 24 Krongrad E. Prognosis for patients with congenital heart disease and postoperative intraventricular conduction defects. *Circulation* 1978; **57**: 867-70.
- 25 Moss A J, Klyman G, Emmanouilides G C. Late onset complete heart block. Newly recognized sequela of cardiac surgery. *Am J Cardiol* 1972; **30**: 884-7.
- 26 Godman M J, Roberts N K, Izukawa T. Late post-operative conduction disturbances after repair of ventricular septal defect and tetralogy of Fallot. *Circulation* 1974; **49**: 214-21.
- 27 Izukawa T, Trusler G A, Williams W G. Effect of transient heart block occurring at the time of closure of ventricular septal defects on the incidence of late complete heart block. In: Meere C, ed. *Proceedings of the Sixth World Symposium on Cardiac Pacing, Montreal, Canada 1979*. Montreal: Pacesymp, 1979: chapter 23-5.
- 28 Wolff G S, Rowland T, Ellison R C. Surgically induced right bundle branch block with left anterior hemiblock. An ominous sign in post operative tetralogy of Fallot. *Circulation* 1972; **46**: 587-94.
- 29 Steeg C N, Krongrad E, Davachi F, Bowman F O, Jr, Malm J R, Gersony W M. Postoperative left anterior hemiblock and right bundle branch block following repair of tetralogy of Fallot. Clinical and etiologic considerations. *Circulation* 1975; **51**: 1026-9.
- 30 Cairns J A, Dobell A R C, Gibbons J, Tessler I. Benign prognosis of right bundle branch block and left anterior hemiblock after intracardiac repair of tetralogy of Fallot (abstract). *Am J Cardiol* 1974; **33**: 129.
- 31 Horowitz L N, Simon M B, Spear J F, et al. The mechanism of apparent right bundle branch block after transatrial repair of tetralogy of Fallot. *Circulation* 1979; **59**: 1241-52.
- 32 Hobbins S M, Izukawa T, Radford D J, Williams W G, Trusler G A. Conduction disturbances after surgical correction of ventricular septal defect by the atrial approach. *Br Heart J* 1979; **41**: 289-93.
- 33 Sung R J, Tamer D M, Garcia O L, Castellanos A, Myerburg R J, Gelband H. Analysis of surgically-induced right bundle branch block pattern using intracardiac recording techniques. *Circulation* 1976; **54**: 442-6.
- 34 Yabek S M, Jarmakani J M, Roberts N K. Diagnosis of trifascicular damage following tetralogy of Fallot and ventricular septal defect repair. *Circulation* 1976; **55**: 23-7.
- 35 El-Said G, Rosenberg H S, Mullins C E, Hallman G L, Cooley D A, McNamara D G. Dysrhythmias after Mustard's operation for transposition of the great arteries. *Am J Cardiol* 1972; **30**: 526-32.
- 36 Gillette P C, Kugler J D, Garson A, Jr, Gutgesell H P, Duff D F, McNamara D G. Mechanisms of cardiac arrhythmias after the Mustard operation for transposition of the great arteries. *Am J Cardiol* 1980; **45**: 1225-30.
- 37 Niederhauser H, Simonin P, Friedli B. Sinus node function and conduction system after complete repair of tetralogy of Fallot. *Circulation* 1975; **52**: 214-20.
- 38 Fox K, Evans T, Rowland E, Krikler D. Bradycardia-tachycardia syndrome 8 years after correction of Fallot's tetralogy. *Eur J Cardiol* 1979; **10**: 109-5.
- 39 Scott O, Macartney F J, Deverall P B. Sick sinus syndrome in children. *Arch Dis Child* 1976; **51**: 100-5.
- 40 Southall D P, Johnston F, Shinebourne E, Johnston P G B. 24 hour electrocardiographic study of heart rate and rhythm patterns in population of healthy children. *Br Heart J* 1981; **45**: 281-91.
- 41 Michaëlsson M, Engle M A. Congenital complete heart block: an international study of the natural history. *Cardiovasc Clin* 1972; **4**: No 3, 86-101.
- 42 Glenn W L. Cardiac pacemaking in infants and children. *Ann Thorac Surg* 1976; **22**: 605-6.
- 43 Morin J E, Pappius E M, Crelinsten G L. Comparison of epicardial and endocardial pacemaker insertion. *Can J Surg* 1977; **20**: 365-8.
- 44 Magilligan D J, Jr, Hakimi M, Davila J. The sutureless electrode: comparison with transvenous and sutured epicardial electrode placement for permanent pacing. *Ann Thorac Surg* 1976; **22**: 80-4.
- 45 Mugica J, Pioeger G, Dubos B, Jaquemast J F, Duconge R, Sanda B. Concerning 1370 myocardial electrodes of various models in active and chronic thresholds, breakage rate, cumulative life expectancy. In: Meere C, ed. *Proceedings of the Sixth World Symposium on Cardiac Pacing, Montreal, Canada 1979*. Montreal: Pacesymp, 1979: chapter 21-8.
- 46 Foale R, Canepa-Anson R, Rickards A F. A 12 year survey of pacing lead failures. In: Meere C, ed. *Proceedings of the Sixth World Symposium on Cardiac Pacing, Montreal, Canada 1979*. Montreal: Pacesymp, 1979: chapter 21-8.
- 47 Goldstein S, Moss A J, Rivers R J, Jr, Weiner R S. Transthoracic and transvenous pacemakers. A comparative clinical experience with 131 implantable units. *Br Heart J* 1970; **32**: 35-45.
- 48 Oldershaw P J, St John Sutton M, Miller G A H, Ward D E. Ten year experience of 359 epicardial pacemaker systems: complications and results. *Clin Cardiol* 1982; in press.
- 49 Young D, Furman S. Cardiac pacing in infants and children. In: Varriale P, Naclerio E A, eds. *Cardiac pacing: a concise guide to clinical practice*. Philadelphia: Lea & Febiger, 1979: 201.
- 50 Lynch M F, Jensen N K, Urdaneta L. Permanent cardiac pacemakers implanted in the pleural space. *J Thorac Cardiovasc Surg* 1978; **76**: 101-7.
- 51 Smyth N P O. Question and answer. *PACE* 1978; **1**: 406-7.
- 52 Morgan G, Ginks W, Siddons H, Leatham A. Septicemia in patients with an endocardial pacemaker. *Am J Cardiol* 1979; **44**: 221-4.
- 53 Siddons H. Transvenous pacing in the child. *Ann Cardiol Angelol (Paris)* 1971; **20**: 445-7.
- 54 Furman S, Young D. Cardiac pacing in children and adolescents. *Am J Cardiol* 1977; **39**: 550-8.
- 55 McNeill G P, Taylor N C. Use of subclavian vein for permanent cardiac pacing. *Br Heart J* 1978; **40**: 114-6.
- 56 Holmes D R, Jr, Maloney J D, Feldt R H. The use of the percutaneous subclavian technique for permanent cardiac pacing in childhood. *Mayo Clin Proc* 1980; **55**: 579-82.
- 57 Bisping H J, Kreuzer J, Birkenheier H. Three year clinical experience with a new endocardial screw in lead with introduction protection for use in the atrium and ventricle. *PACE* 1980; **3**: 424-35.

- ⁵⁸ Fraedrich G, Mulch J, Hehrlein F W. Endocardial leads for pacing in infancy (abstract). *PACE* 1981; 4: A46.
- ⁵⁹ Hayes D L, Maloney J D, Neubauer S A, Ritter D G. Effectiveness of transvenous endocardial pacing in the paediatric age group (abstract). *PACE* 1981; 4: A49.
- ⁶⁰ MacGregor D C, Wilson G J, Dutcher R G, *et al.* A new positive fixation endocardial pacemaker lead using an extendable/retractable helix. In: Meere C, ed. *Proceedings of the Sixth World Symposium on Cardiac Pacing, Montreal, Canada 1979*. Montreal: Pacesymp, 1979: chapter 29–14.
- ⁶¹ Hellestrand K, Ward D E, Bexton S, Camm A J. The use of active fixation electrodes for permanent endocardial pacing via a persistent left superior vena cava. *PACE* 1981; 5: 180.
- ⁶² Upton J E. New pacing lead conductors. In: Meere C, ed. *Proceedings of the Sixth World Symposium on Cardiac Pacing, Montreal, Canada 1979*. Montreal: Pacesymp, 1979: chapter 29–6.
- ⁶³ Richer G J, Weidlich E, Sturm F, *et al.* Nonpolarizable vitreous carbon electrodes in animal experiments. In: Meere C, ed. *Proceedings of the Sixth World Symposium on Cardiac Pacing, Montreal, Canada 1979*. Montreal: Pacesymp, 1979: chapter 29–13.
- ⁶⁴ Sutton R, Perrins J, Citron P. Physiological cardiac pacing. *PACE* 1980; 3: 207–19.
- ⁶⁵ Griffin J C, Quitman J A. Pacemaker programmability in the role of non-invasive pacing system revision. In: Meere C, ed. *Proceedings of the Sixth World Symposium on Cardiac Pacing, Montreal, Canada 1979*. Montreal: Pacesymp, 1979: chapter 19–3.

Correspondence to Dr D E Ward, Cardiology Department, Brompton Hospital, Fulham Road, London SW3 6HP.

Received 18 January 1982

The following articles will appear in future issues of this journal:

Cystic fibrosis: physical exercise versus chest physiotherapy
M Zach, B Oberwaldner, and F Häusler

Evaluation of a height/plasma creatinine formula in the measurement of glomerular filtration rate
M C Morris, C W Allanby, P Toseland, G B Haycock, and C Chantler

Natural history of egg hypersensitivity
R P K Ford and B Taylor

Circulating soluble immune complexes containing pseudomonas antigens in cystic fibrosis
R W Pitcher-Wilmott, R J Levinsky, and D J Matthew

Sudden natural death in later childhood and adolescence
N Molander

Poor weight gain of the low birthweight infant fed nasojejunally
M F Whitfield

Phenobarbitone dosage in neonatal convulsions
R A Ouvrier and R Goldsmith