Long-Term Management of Bradyarrhythmias Following Open Heart Surgery: Surgical A-V Block and Sick Sinus Syndrome after Surgery for Secundum Atrial Septal Defects Treated with Permanent Cardiac Pacing

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Postoperative clinical findings from 25 patients with surgical A-V block and 12 with SSS following surgery for ASD who received permanent pacemakers were analyzed in order to consider the long-term management of postoperative bradyarrhythmias.

(1) Surgical A-V block: Episodes of Adams-Stokes were observed in 11/25 patients before pacemaker implantation, and in 6 of these (55%) the onset of episodes occurred more than a year after open heart surgery. Of 8 cases for which ECG's during Adams-Stokes were available, 2 had bifascicular or trifascicular block which progressed to complete A-V block below the His bundle. The 6 others (75%) had ventricular tachycardia or ventricular flutter-fibrillation during Adams-Stokes. 2 of these had blocks above the His bundle. 4/25 had improvement of complete A-V block within a month. Following pacemaker implantation, 3 died of heart failure and 3 of sudden death. 5 year survival was 70%. Therefore, surgical A-V block requires careful long-term management, and the presence of ventricular tachyarrhythmias as well as the location of block are important predictors of patient risk.

(2) SSS after surgery for ASD: 10/12 patients had Adams-Stokes, of which 6 (60%) had initial onset over 5 years after surgery, and 9 had paroxysmal atrial flutter and fibrillation which coincided with the onset of Adams-Stokes. 3 of 7 patients (42%) for whom preoperative ECG's were available had sinus bradycardia. Thus, SSS after ASD surgery may be preceded by preoperative deterioration of sinus node function and succeeded by late onset of Adams-Stokes, necessitating pre- and postoperative assessment of sinus node function. The presence of atrial tachyarrhythmias also serves as an important indicator of the severity of SSS after ASD surgery.

The onset of Adams-Stokes varied by patient over a wide range of time, emphasizing the need for careful long-term follow-up. Clinical symptoms and prognosis were affected by tachyarrhythmias as well as the severity of the bradycardia. Therefore, the presence of ventricular/atrial tachyarrhythmias is an important factor in the long-term management of postoperative bradyarrhythmias.

Key Words:

Surgical A-V block
Sick sinus syndrome
Atrial septal defect
Adams-Stokes Syndrome
Tachyarrhythmia

IMPROVEMENTS in open heart surgery have resulted in greater longevity and a better quality of life for patients with congenital and acquired heart disease. However, added years of follow-up seem to indicate that more patients who receive surgery suffer various dysarrhythmias

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and late sudden death. Bradyarrhythmias after open heart surgery often lead to serious clinical complications, including Adams-Stokes attacks, congestive heart failure, and sudden death. In most patients bradyarrhythmias result from acute damage to the conduction system during surgery. In some cases arrhythmias may be associated with preoperative conduction disturbances and abnormal impulse generation, or postoperative fibrosis around the cannulation or suture sites. Often bradyarrhythmias appear immediately after surgery and persist for the rest of the patient's life. Late development of bradyarrhythmias may also occur.

The purpose of this study is to review the long-term prognosis of patients who received permanent pacemakers for atrioventricular (A-V) block and sick sinus syndrome (SSS) resulting from surgery for secundum atrial septal defects (ASD). Problems occurring during the course of long-term follow-up are also discussed.

MATERIAL AND METHODS

The study population consisted of patients who received permanent pacemakers for (1) surgical A-V block, and (2) SSS after surgery for ASD.

(1) Surgical A-V Block

Twenty-five paced patients who had post-operative A-V block at the Heart Institute of Japan, Tokyo Women's Medical College, between 1963 and 1979 were studied. There were 15 males and 10 females. Age at the time of surgery ranged from 1 to 46 years (mean age 20). Time from open heart surgery to permanent pacemaker implantation ranged from 0 to 7.3 years (mean 1.3 years) and the follow-up period after implantation ranged from 1 month to 16.2 years (mean 6 years).

The patients were grouped according to their pre-implant conditions: Group I, with Adams-Stokes before implantation; Group II, without Adams-Stokes before implantation; and Group III, with congestive heart failure (CHF).

In Group I, age at the time of surgery ranged from 5 to 46 years (mean age 21). Time from open heart surgery to pacemaker implantation ranged from 18 days to 6.8 years (mean 2.1 years) and the follow-up period after pacemaker implantation ranged from 2.5 months to 16.2 years (mean 7.4 years). In Group II, age at the time of surgery ranged from 3 to 46 years (mean

TABLE I PREOPERATIVE CARDIOVASCULAR DIAGNOSIS OF 25 PATIENTS WITH SURGICAL A-V BLOCK

Cardiovascular diagnosis	No. of patients
ECD	8
T/F	4
VSD	3
VSD $\bar{c}$ ASD $\bar{c}$ PDA	1
VSD $\bar{c}$ DORV $\bar{c}$ MR	1
VSD $\bar{c}$ TGA $\bar{c}$ PS	1
VSD $\bar{c}$ AR	2
AR and/or MR	5
Total	25

Abbreviations: ECD = endocardial cushion defect; T/F = tetralogy of Fallot; VSD = ventricular septal defect; ASD = atrial septal defect; PDA = patent ductus arteriosus; DORV = double outlet right ventricle; TGA = transposition of the great arteries; PS = pulmonary stenosis; MR = mitral regurgitation; AR = aortic regurgitation.

age 21). Time from open heart surgery to pacemaker implantation ranged from 0 to 4.3 years (mean 0.2 years) and post-implant follow-up ranged from 1.2 to 9.5 years (mean 5.3 years). In Group III, age at the time of surgery ranged from 1 to 38 years (mean 15). Time from open heart surgery to pacemaker implantation ranged from 3 days to 7.3 years (mean 2.4 years) and the post-implant follow-up ranged from 1 month to 7 years (mean 3.1 years).

(2) SSS after Surgery for ASD

Twelve paced patients who developed SSS after ASD surgery were studied. ASD operations were performed between 1956 and 1981. 7 cases were performed at the Heart Institute of Japan, Tokyo Women's Medical College, and 5 were performed at other institutions. There were 2 males and 10 females, 6 to 51 years old (mean 23 years) at the time of ASD repair and 13 to 51 years old (mean 32 years) at the time of pacemaker implantation. Time from ASD operation to pacemaker implantation ranged from 22 days to 25 years (mean 9 years) and post-implant follow-up ranged from 11 months to 5.9 years (mean 3.5 years).

Electrophysiologic Study: (1) Surgical A-V block

Electrophysiologic (EP) studies were per-

TABLE II CLINICAL DATA OF 25 PATIENTS WITH SURGICAL A-V BLOCK

Patient No.	Age at operation	Sex	Cardiovasc disease	ECG		Postop time to Adams-Stokes	ECG during Adams-Stokes block	Site of block	Postio time to PM implant	Outcome	
				Preoperative	Postoperative					Follow up after PM implant	Alive(A) or dead(D)
Group I (with Adams-Stokes attack)											
1	39	M	VSD ± AR	CLBBB	CRBBB + LAH → II° AVB	2m	Asystole	HV	2m	2m16d	D CHF
2	22	F	VSD ± AR	N	CRBBB + LAH → II° AVB	2y8m	Asystole	HV	2y9m	5y2m	D CHF
3	46	F	AR(AAE)	N	III° AVB	1m	VT·Vf	HV	2m	4y8m	A
4	39	F	AR(AAE)	N	III° AVB	18d	VT·Vf	HV	18d	6y9m	A
5	5	M	VSD	N	III° AVB	2m	unknown	—	2m	16y2m	A
6	13	M	T/F	N	III° AVB	1m	VT·Vf	—	1m	11y7m	A
7	5	M	T/F	N	III° AVB	5y9m	VT·Vf	HV	5y10m	1y10m	A
8	24	M	ECD	N	III° AVB	1y2m	VT·Vf	AH	1y2m	11y2m	A
9	8	F	ECD	N	III° AVB	2y7m	unknown	AH	2y10m	14y7m	A
10	30	M	ECD	N	II° → III° AVB	3y2m	unknown	—	3y8m	7y1m	A
11	4	F	ECD	N	II° → III° AVB	6y10m	VT·Vf	AH	6y10m	2y1m	D sudden death
Group II (without Adams-Stokes attack)											
12	12	F	ECD	I° AVB	III° AVB	—	—	—	12d	7y10m	A
13	10	F	ECD	I° AVB	III° AVB	—	—	—	21d	6y5m	A
14	39	M	ECD	I° AVB	III° AVB	—	—	AH	1m	9y6m	A
15	6	F	ECD	N	III° AVB	—	—	—	1m	2y	D sudden death
16	46	M	MR	I° AVB	III° AVB	—	—	—	16d	7y10m	A
17	42	M	ASR ± MSR	N	III° AVB	—	—	HV	5d	4y7m	A
18	7	M	VSD	N	III° AVB	—	—	—	1m12d	1y2m	D hepatitis
19	3	M	VSD ± DORV ± MR	N	II° → I° AVB + CRBBB → CRBBB	—	—	—	15d	1y5m	D sudden death
20	4	M	T/F	N	III° AVB → CRBBB + LAH	—	—	—	0d	5y10m	A
21	29	M	T/F	N	II° AVB	—	—	AH	2y4m	6y8m	A
22	30	M	AR ± MR	N	III° → II° AVB	—	—	AH	1m15d	5y4m	A
Group III (with CHF)											
23	7	F	VSD ± d TGA ± PS	N	I° AVB	—	—	—	3d	1m	D CHF
24	1	M	VSD ± PDA ± ASD	N	III° → II° AVB	—	—	—	16d	2y4m	D CHF
25	38	F	VSD	N	II° → III° AVB	—	—	—	7y3m	7y	A

Postop = postoperative; AAE = aortic ectasia; CLBBB = complete left bundle branch block; CRBBB = complete right bundle branch block; LAH = left anterior hemiblock; AVB = AV block; N = normal rhythm; y = year; m = month; d = day; VT·Vf = ventricular tachycardia, flutter and fibrillation.

Fig.1. Electrocardiographic developments in Group I patients with Adams-Stokes.

formed at the time of pacemaker implantation in 12 of 25 patients with surgical A-V block. A 5 or 6 Fr bipolar electrode catheter was introduced percutaneously through the femoral vein and placed across the tricuspid valve to record low right atrial, His bundle, and ventricular potentials. These were recorded, along with ECG's from 3 surface leads (I, II, and VI), on a photographic recorder at a 100 mm/sec paper speed.

Electrophysiologic Study: (2) SSS after Surgery for ASD

EP studies were performed in all patients at the time of pacemaker implantation using a 5 or 6 Fr quadripolar catheter in the high right atrium. Kasanuki's protocol¹ for atrial pacing was utilized, stimulating for 30 seconds while increasing the rate at 10 beat/min increments up to 200 beats/min. ECG's were recorded at a paper speed of 50 or 100 mm/sec. Maximum

sinus node recovery time (Max SRT) or maximum junctional recovery time (Max JRT) was measured in all cases.

Follow-up:

Each patient's chart was reviewed for details of operative procedure, postoperative course, electrocardiographic findings, and long-term prognosis after open heart surgery and pacemaker implantation.

RESULTS

(1) Surgical A-V Block

Each patient's preoperative diagnosis by cardiac catheterization is listed in Table I. 12 patients had ventricular septal defects: 4 tetralogy of Fallot, 3 ventricular septal defects without other anomalies. 1 patent ductus arteriosus and ostium secundum atrial septal defect, 1 double

Fig. 2. Case 2, VSD+AR, female, 22 years. Bifascicular block developed after surgery. 33 months after surgery syncope occurred, and complete A-V block was noted, which persisted. Site of block was below the His bundle. Pacemaker therapy abolished Adams-Stokes, but patient died of CHF 62 months later.

outlet right ventricle with mitral regurgitation, 1 transposition of the great arteries, and 2 ventricular septal defects with aortic regurgitation. Besides these ventricular septal defects, there were 8 endocardial cushion defects, 5 with valvular heart disease, including 2 aortic regurgitation with anuloaortic ectasia, 2 with combined valvular disease of the aortic and mitral valves, and 1 with mitral regurgitation.

Pre- and postoperative electrocardiographic rhythms are shown in Table II. 20 of 25 patients had normal rhythm before surgery. 5 patients had preoperative conduction abnormalities, of which 4 had 1st degree A-V block and 1 had complete left bundle branch block (CLBBB). Complete A-V block developed perioperatively in 18 patients. 4 of these patients improved within a month after surgery. Complete A-V block persisted in the other 14. Trifascicular and bifascicular block developed in 2 separate cases. Each progressed to complete A-V block 2 months and 2.8 years after surgery, respectively. 2nd degree A-V block developed in 5 patients postoperatively. 3 of these progressed to complete block after 1 year or more, and 2 remained

in 2nd degree A-V block. EP studies were performed in 12 patients at the time of pacemaker implantation. The site of block was above the His bundle (AH) in 6 patients and below the His bundle (HV) in another 6.

Group I (with Adams-Stokes)

Group I consisted of 11 patients in whom pacemakers were implanted following episodes of Adams-Stokes attacks (Table II, Fig. 1). In 10 of the 11 patients preoperative ECG's showed normal sinus rhythm, and only one (case 1) had CLBBB. Postoperatively, 7 of 11 patients (cases 3-9) had complete A-V block with no improvement during follow-up. Two patients showed trifascicular or bifascicular block (cases 1, 2), and in these patients the bundle branch block progressed to complete A-V block 2 months and 2.7 years after surgery, respectively. In two other patients (cases 10, 11) postoperative ECG's showed Wenckebach 2nd degree A-V block, which progressed to complete A-V block after 3 and 1 years, respectively.

Postoperative time until the onset of Adams-Stokes ranged from less than 1 month to 6.8 years (mean 2.1 years). In 5 patients the attacks

Fig.3. Case 7. Tetralogy of Fallot, male, 5 years. Complete A-V block developed after intracardiac repair. Ventricular rhythm was stable, so pacemaker was not implanted. 69 months later, patient was admitted with syncope. ECG during syncope showed ventricular flutter but no asystole. EP study showed blockage below the His bundle, and pacemaker was implanted. Patient has subsequently been followed for 22 months with no Adams-Stokes.

occurred within 2 months (cases 1, 3–6). In the other 6, the attacks occurred after more than a year (cases 2, 7–11). ECG's during Adams-Stokes attacks were available for 8 patients. These showed ventricular asystole in the 2 patients (cases 1, 2) with trifascicular or bifascicular block (Fig. 2). In the other 6, Adams-Stokes was caused by ventricular tachycardia and ventricular flutter-fibrillation (VT-Vf) (Fig. 3). All 6 of these patients also had complete A-V block before Adams-Stokes. Of the 8 patients in which the site of the conduction block was assessed, 3 were found to have AH block and 5 had HV block.

None of the patients experienced subsequent episodes of Adams-Stokes after pacemaker therapy. However, 3 patients died. 2 with ventricular septal defects and aortic regurgitation died of CHF 2.5 months and 5.2 years after pacemaker implantation; Another with ECD died suddenly 2.1 years after implantation.

Group II (without Adams-Stokes)

Group II consisted of 11 patients in whom

pacemakers were implanted prophylactically to prevent Adams-Stokes (Table II, Fig. 4). Preoperative ECG's showed normal sinus rhythm in 7 patients and 1st degree A-V block in 4. Postoperative ECG's showed complete A-V block in 10 patients and 2nd degree A-V block in one. Of the 10 patients with complete A-V block, 2 reverted to sinus rhythm and one to 2nd degree block within a month after surgery. The site of block, for 4 patients in which it was determined, was AH in one and HV in 3.

There were no episodes of Adams-Stokes after pacemaker implantation. However, among 3 mortalities, one who had ECD repair died suddenly 2 years after surgery, and another who had ventricular septal defects with double outlet right ventricles and mitral regurgitation died suddenly 1.3 years after surgery. Another patient with ventricular septal defect died of hepatitis 1.5 years postoperatively.

Group III (with CHF)

Group III consisted of 3 patients in whom pacemakers were implanted for CHF (Table II,

Fig.4. Electrocardiographic developments in Group II patients without Adams-Stokes.

Fig.5. Electrocardiographic developments in Group III patients with CHF.

TABLE III CLINICAL DATA OF 12 PATIENTS WITH SSS AFTER SURGERY FOR ASD

Patient No.	Age at operation (yrs)	Sex	Preoperative ECG	ECG at time of PM implant	Postop time to P-af-AF	Adams-Stokes	Postop time to Adams-Stokes	Max SRT at time of PM implant (msec)	Postop time to PM implant	Outcome	
										Follow up after PM implant	Alive (A) or Dead (D)
1	51	F	chronic af	N SA ⁺ P-af	1d	(+)	10d	5360J	22d	4y4m	A
2	44	F	chronic af	SB SA	(-)	(+)	20d	4480J	7m	2y9m	A
3	50	M	SB, P-AF	SB SA ⁺ P-AF	6d	(+)	6d (preop 3d)	5200	1m	3y7m	A
4	19	F	SB	SB SA	(-)	(+)	8m	7500J	6y5m	4y9m	A
5	33	F	SB	SB SA ⁺ P-AF	9y4m	(+)*	9y4m	4480J	6y5m	3y2m	A
6	6	F	N	SB SA P-AF	7y2m	(+)	8y	7200J	11y8m	11m	A
7	7	F	N	SB SA ⁺ P-AF	1m/5y6m	(+)*	5y6m	7000	7y5m	5y11m	A
8	20	F	-	SB SA P-AF	9y	(+)*	9y	2020J	10y	5y7m	A
9	13	F	-	N SA ⁺ P-AF	25y	(+)	25y	7160	25y	3y4m	A
10	19	F	-	SB SA P-AF	18y3m	(+)*	18y	8400	18y	11m	A
11	6	M	-	SB SA P-AF	6y6m	(-)	(-)	5500J	6y9m	2y9m	A
12	6	F	-	SB SA	(-)	(-)	(-)	6180	15y	11m	A

Postop = postoperative; af = atrial fibrillation; AF = atrial flutter; P = paroxysmal; SB = sinus bradycardia; SA = sinus arrest; SA⁺ = sinus arrest only after P-af-AF; N = normal rhythm; d = day; y = year; m = month; J = junctional escape; * = syncope

Fig. 6. Survival curve of paced patients with A-V block.

Fig. 5). Preoperative ECG's showed normal rhythm, while postoperative ECG's showed 2nd degree A-V block in 2 patients and complete A-V block in one. The patient with complete A-V block improved to 2nd degree block, and one patient with 2nd degree A-V block developed complete A-V block.

In 2 cases pacemakers facilitated pharmacological therapy and improved heart failure, but two patients eventually died of CHF, 1 month and 2.4 years postoperatively.

Prognosis after pacemaker implantation

Of the 25 paced patients, 8 died 1 month to 8.9 years postoperatively. Cause of death was CHF in 4 cases, sudden death in 3, and extracardiac disease in another. There were no pacemaker-related deaths. Figure 6 compares the cumulative survival of paced patients with surgical A-V block to that of paced patients with all forms of A-V block, as well as to paced patients with conduction block without organic heart disease at our institute. Survival rates for surgical A-V block, all A-V block, and A-V block without organic heart disease were 92%, 90%, and 94% after 1 year, 76%, 83%, and 90% after 3 years, 70%, 78%, and 84% after 5 years, and 59%, 74%,

Fig.7. Electrocardiographic developments in patients with SSS after surgery for ASD.

and 79% after 10 years, respectively.

(2) SSS after surgery for ASD

Clinical description

Preoperative ECG's were available for 7 of 12 patients (Table III, Fig. 7). Of these 7 patients, 2 had sinus bradycardia of less than 50 bpm (cases 4, 5), one had paroxysmal atrial flutter and sinus bradycardia (case 3), and 2 had chronic atrial fibrillation (cases 1, 2). In cases 2, atrial fibrillation persisted after surgery and required electrical cardioversion. Progression of sinus bradycardia and sinus arrest was noted in 5 patients whose ECG's were followed for more than 6 years postoperatively (cases 4, 5, 6, 7, 11), (Figs. 7, 8).

At the time of pacemaker implantation, sinus bradycardia was present in 10 of 12 patients. Of these, 3 had only bradycardia (cases 3, 5, 7), while 7 had bradycardia and paroxysmal sinus arrest (cases 2, 4, 6, 8, 10, 11, 12). Another 2 showed normal sinus rhythm (cases 1, 9). In patients with only sinus bradycardia or normal sinus rhythm, sinus arrest was seen after cessation of paroxysmal atrial flutter or fibril-

lation (P-af-AF). P-af-AF was seen in 9 patients; in 7 it occurred 5 years after ASD repair. 10 patients had Adams-Stokes attacks (cases 1-10), of which 4 had syncope (cases 5, 7, 8, 10) and the other 6 faintness. Patients suffering syncope all had P-af-AF. Adams-Stokes attacks occurred immediately after surgery in 4 patients (cases 1-4), and more than 5 years later in 6 (cases 5-10). Onset of Adams-Stokes seemed to coincide with the onset of P-af-AF. Of the 2 patients without Adams-Stokes episodes, one experienced symptoms of general fatigue, shortness of breath, and pretibial edema due to bradycardia (case 11), and the other was asymptomatic (case 12).

Electrophysiologic Study

Max SRT at the time of pacemaker implantation is listed in Table III. It was longer than 4000 msec in all patients (mean 5873 msec), except for one case where a junctional rhythm superseded the sinus rhythm (case 8).

In case 3, EP studies were performed before and after ASD surgery. Max SRT was 3900 msec before surgery and increased to 5200 msec one month after surgery. In cases 6, EP studies

Fig.8. Case 6. SSS after surgery for ASD, female, 6 years at the time of operation. A case in whom gradual deterioration of sinus node function after ASD closure is suspected. Normal sinus rhythm was present after surgery, but sinus bradycardia appeared around the 2nd year postop. ECG of March 1978 showed sinus bradycardia with junctional escape rhythm. P-AF developed and faintness was reported 86 months postop. ECG revealed paroxysmal sinus arrest and post-P-AF arrest. JRT of June 1979 was 1920 msec, which progressed to 7200 msec by March 1984. Arrows indicate Adams-Stokes episodes.

performed at a 4 year interval demonstrated prolongation of the JRT from 1920 to 7200 msec (Fig. 8).

Preoperative hemodynamic data and operative findings

Data from preoperative catheterizations, operative findings and procedures are summa-

rized in Table IV. Preoperative hemodynamic data was available for 6 of 12 patients. Pulmonary hypertension was present in all cases, and was mild in 3, moderate in 2, and severe in one. Left to right shunt ratio ranged from 38% to 82% (mean 59%).

In 8 of 12 patients operative procedure was

TABLE IV PREOPERATIVE HEMODYNAMIC STUDIES AND OPERATIVE FINDINGS

Patient No.	Preoperative hemodynamic study			Defect (cm)	Operative procedure
	RA	PA	L → R shunt (%)		
1	12	52/19 (28)	82	2.0 × 2.7 : central	patch closure
2	8	44/20 (29)	75	2.5 × 2.5 : central	patch closure
3	6	65/25 (41)	38	5 × 3 : central	patch closure
5	11	37/12 (21)	42	2.5 × 2.5 : central	direct closure
6	15	58/30 (42)	42	4 × 1 : central	direct closure
7	4	33/9 (20)	77	4 × 1 : central	direct closure
10	—	—	—	3 × 2 : central	direct closure
11	—	—	—	3 × 4 : central	direct closure

In patient No.4, 8–12 preoperative studies and operative findings are unknown.

RA = right atrial mean pressure, mmHg; PA = pulmonary artery pressure, mmHg (systolic/diastolic); () = mean pressure

confirmed. All had central ASD: 5 were repaired by direct closure and 3 with a patch.

Prognosis after pacemaker implantation

All patients are alive, and have been followed for 11 months to 5.9 years (mean 3.5 years) after pacemaker implantation. There were no episodes of Adams-Stokes and in 3 patients chronic atrial fibrillation or flutter developed after implantation.

DISCUSSION

(1) Surgical A-V block

Surgical A-V block is often accompanied by Adams-Stokes episodes, heart failure, and sudden death. These complications require careful long-term management. Improved surgical techniques and better understanding of the conduction system anatomy have reduced the incidence of surgical A-V block² but for certain cardiac conditions and operative procedures it remains inevitable.

Cardiac Conditions

Surgical A-V block occurs most commonly during and after surgical correction of ventricular septal defects,³ tetralogy of Fallot,^{4,5} ECD,^{2,6} corrected transposition of the great arteries,⁷ and valve replacements⁸ requiring manipulation in the vicinity of the conduction system. Among the 25 cases of surgical A-V block for which pacemakers were implanted in this study, A-V block arising from VSD closure procedures was most common with 12 cases, of which 4 involved tetralogy of Fallot. A-V block arising from ECD repair was also quite common, involving 8 cases. Surgical intervention for these conditions

therefore requires considerable care to protect the conduction system.

Onset of Adams-Stokes

The main purpose of pacemaker implantation following surgical A-V block is to prevent Adams-Stokes and to ameliorate congestive heart failure. The onset of Adams-Stokes is always unpredictable. Our study includes 11 patients (44%) in whom pacemakers were implanted after the occurrence of Adams-Stokes episodes (see Group I). The initial onset of Adams-Stokes ranged over a wide period, from 18 days to 6.8 years after surgery, but the fact that 55% occurred more than a year later is noteworthy. Delayed onset of Adams-Stokes is especially hazardous because it may occur without warning in otherwise healthy patients and may lead to sudden death. Therefore, patients with surgical A-V block require careful supervision not only immediately following surgery but over the long run as well.

Electrocardiographic developments

Of the patients in this study, 56% had sustained complete A-V block immediately following surgery, but some exhibited a late onset of A-V block, as in cases 1, 2, 10, 11, and 25. Others suffered transient complete A-V block, as in cases 19, 20, 22, and 24.

Bifascicular Block

In cases 1 and 2, postoperative ECG's showed trifascicular and bifascicular block, which progressed to complete A-V block with Adams-Stokes attacks after 2 months and 2.6 years, respectively. Such late onset of complete A-V block should be kept in mind during follow-up of patients with surgical A-V block. Traditionally, postoperative

bifascicular block has warranted clinical consideration as a frequent forerunner of complete A-V block, with the potential for Adams-Stokes attacks and even sudden death.^{9,10} The significance of this conduction disturbance, however, has been the subject of controversy, as a favorable prognosis has been found by Downing et al,¹¹ Cavin et al,¹² and Steeg et al.¹³ Variation in the long-term prognosis for patients with bifascicular block may result in part from differences in the site of injury. In cases 1 and 2, electrophysiologic studies showed the site of block to be below the His bundle. The assessment of conduction abnormalities in the His-Purkinje system is important for patients with bifascicular block. The usefulness of EP studies to assess whether bifascicular block will develop into complete A-V block has been discussed and it is now considered that prolongation of the HV interval^{14,15} and the development of 2nd degree HV block by atrial pacing¹⁶ or pharmacological testing^{17,18} may be significant. However, the significance of these findings is still disputed.¹⁹ Furthermore, because their significance has been researched primarily as it relates to elderly patients with ischemic heart disease, it may be even harder to apply it to patients with postoperative bifascicular block. Therefore, their clinical relevance requires further investigation.

Transient complete A-V block

Postoperative A-V block is often transient in nature. In our study, 1:1 conduction resumed within 4 weeks postoperatively in cases 19 and 20, which initially had complete A-V block. It may be suspected, then, that the implantation of pacemakers was not necessary in these cases. Therefore, patients should be monitored under temporary pacing during the acute postoperative stage, and it is recommended that a permanent pacemaker be implanted only if complete A-V block persists beyond 4 weeks. On the other hand, Krongrad et al²⁰ claim that transient complete heart block in the immediate postoperative period predicts late development of complete heart block or sudden death. Thus, conductivity of the His-Purkinje system should be assessed with EP studies to determine whether there is any need to implant a pacemaker.

Persistent complete A-V block

In order to determine the severity of complete A-V block, Driscoll et al²¹ consider EP assessment of the site of block to be important. Specifically, if the blockage is above the His bundle, asystolic episodes are unlikely because

supraventricular rhythm will be adequately maintained, and therefore a pacemaker is not necessary. On the other hand, if the blockage is within or below the His bundle, then asystole is likely and a pacemaker is warranted. Of the 8 patients in this study with Adams-Stokes whose HBE were recorded, 5 had HV block but 3 had blocks above the His bundle, indicating the difficulty of predicting the likelihood of Adams-Stokes from the site of block alone.

Clinical significance of VT•Vf

Of the 12 patients with Adams-Stokes (Group I), ECG's during episodes of Adams-Stokes were recorded in 8. Of these, only 2 (25%) were asystolic, while VT•Vf occurred in 6 (75%). All 6 had complete A-V block before the onset of Adams-Stokes. 2 of the 3 patients with AH block had VT•Vf during Adams-Stokes attacks, while no ECG during Adams-Stokes was available for the 3rd. This indicates that ventricular tachyarrhythmias play an important role along with the site of block in the onset of Adams-Stokes in persistent complete A-V block. Furthermore, 5 of the 6 patients with VT•Vf who received permanent pacemakers had no recurrence of VT•Vf or Adams-Stokes. This fact indicates the efficacy of pacemaker therapy in preventing these complications. From this it is also assumed that bradycardia due to complete A-V block, combined with severe cardiac conditions, facilitates ventricular premature contractions and VT•Vf. Accordingly, the presence and severity of ventricular tachyarrhythmias should be considered as an important indicator for pacemaker implantation in patients with complete postoperative A-V block.

Indications for implantation of permanent pacemakers

Disagreement exists over the efficacy of and indications for pacemaker implantation in patients with postoperative A-V block, especially children. Several authors^{22,23,24} advocate pacemaker therapy on the grounds that it improves mortality. Others^{25,26} describe successful long-term management of postoperative complete A-V block without the use of pacemakers. These variations are thought to be due to differences in location of block, extent of injury to the His-Purkinje system, and presence or lack of ventricular tachyarrhythmias as well as differences in the underlying cardiac conditions. We therefore recommend pacemaker implantation in the following: (1) Cases with Adams-Stokes. (2) Cases in which complete

A-V block persists for more than 4 weeks postoperatively with the site of block being located within or below the His bundle, or above the His bundle with severe ventricular tachyarrhythmias. (3) Cases of bifascicular or transient complete heart block in which EP studies using atrial pacing and pharmacological testing in the 4th postoperative week reveal 2nd degree HV block. (Indication may be extended to cases with bifascicular or complete block in which HV interval prolongation is noted and pharmacological therapy is required to suppress premature ventricular contractions.) (4) Cases of congestive heart failure or low cardiac output due to complete A-V block which is not amenable to pharmacological treatment. In addition to the above criteria, it is also necessary to consider the severity of the underlying cardiac condition, and to give special consideration to pediatric cases. Patients with bifascicular, transient complete A-V, or persistent complete A-H block who do not receive pacemakers should be checked periodically by 24 hour Holter monitoring for progression of block and ventricular tachyarrhythmias. This careful monitoring should be continued on a long-term basis.

Prognosis and treatment after pacemaker implantation

The survival rate for pacemaker patients with surgical A-V block is only 70% at 5 years, which is obviously less than optimal. Of the 25 cases in this study, 4 died of CHF and 3 of sudden death. Therefore, long-term follow-up of paced patients should pay special attention to CHF and ventricular tachyarrhythmias.

(2) SSS after surgery for ASD

Among bradyarrhythmias that accompany open heart surgery, there are frequent reports of sinus node dysfunction following surgical repair of ASD²⁷⁻³². However, there are few studies that examine sick sinus syndrome after surgery for ASD in sizable populations.

Mechanism of SSS after surgery for ASD

Traditionally, sinus node dysfunction following ASD surgery was thought to result from surgical damage to the sinus node or its artery^{27,28,29}. However, there are some cases in which abnormalities of the sinus node have been found even before surgery^{33,34,35}. In our experience, sinus bradycardia was present in 3 of 7 patients (42%) for which preoperative ECG's were available, and one of these also had a prolonged SRT, indicating the possibility that sinus node

dysfunction can be present before surgery.

Some investigators have suggested that the hemodynamic force of increased atrial blood flow is responsible for atrial arrhythmias^{30,36}. Clark et al³⁴ noted a correlation between the magnitude of shunt and the presence of sinus node dysfunction. In our experience, 3 (50%) out of 6 cases for which preoperative hemodynamic data were available had a left to right shunt ratio greater than 75%, and 3 (50%) had pulmonary artery pressures exceeding a medium level. It may therefore be thought that the duration of hemodynamic stress has an important influence on sinus node dysfunction. However, the relationship of preoperative hemodynamics to sinus node function was not examined in this study, nor was the sample size sufficiently large to draw firm conclusions regarding the same.

It is also known that sinus node dysfunction occurs more frequently after the repair of sinus venosus ASD than after ostium secundum ASD³³. All cases of ASD in this study were central ostium secundum, though size of defects varied. A correlation was attempted between defect size and sinus node dysfunction, but no conclusion could be drawn.

Greenwood et al²⁷ claim that in cardiopulmonary bypass operations, anchoring sutures to the cannulae in the superior vena cava or displacement of the sump suckers may produce injury to the sinoatrial node or its artery and result in SSS. A comparison of pre- and postoperative EP studies did reveal prolongation of SRT in case 3. Suggesting that surgical procedure may cause SSS in patients undergoing surgery for ASD.

Recently, Clark et al³⁴ suggested that teratogenic influences could affect both atrial septal and sinoatrial development during early cardiac morphogenesis, with the altered morphogenesis presenting clinically as secundum ASD and more subtly as abnormalities in sinus node function. Morphogenetic abnormalities, hemodynamic forces due to shunts, and surgical technique, then, can all contribute to SSS after surgery for ASD.

Electrophysiologic study

The clinical manifestations of SSS after surgery for ASD can vary from pronounced sinus bradycardia, sinus arrest, Adams-Stokes, and heart failure, to none. SSS is usually diagnosed by regular ECG and/or Holter ECG's but EP studies are considered useful in assessing its severity. Almost all patients in this study had

prolongation of SRT over 4 seconds, indicating severe sinus node dysfunction.

Onset of Adams-Stokes

The presence of Adams-Stokes is also relevant to the treatment of SSS. Most patients in this study who received pacemakers for SSS after surgery for ASD had already experienced Adams-Stokes episodes. As for the onset of these attacks, 4 of the 10 patients (40%) with Adams-Stokes first experienced them within one year postoperatively, indicating the need for careful follow-up from an early stage. The fact that all 4 of the above patients had preoperative arrhythmias such as sinus bradycardia or atrial fibrillation further suggests the need for careful pre- and postoperative evaluation of sinus node function in patients with preoperative brady- and tachyarrhythmias. In the 6 remaining patients (60%), the onset of Adams-Stokes occurred more than 5 years postoperatively. Some patients (cases 4, 5, 6, 7, 11) also exhibited a postoperative deterioration in sinus node function over time. Therefore, any patient with SSS who is not paced should be carefully followed over a long-term period.

Clinical significance of P-af•AF

Among the arrhythmias occurring after ASD surgery, it is generally said that bradyarrhythmias are prevalent in the young, whereas tachyarrhythmias prevail in the elderly. Of the 12 patients who received pacemakers in this study, 10 (83%) exhibited atrial flutter and/or fibrillation. Of the 10 patients who experienced Adams-Stokes, 8 (80%) had P-af•AF. Furthermore, P-af•AF was found in all patients with syncope, and the initial onset of Adams-Stokes appeared to coincide with that of P-af•AF. Therefore, atrial tachyarrhythmias are a crucial determinant for the presence and severity of clinical symptoms in patients with SSS after surgery for ASD. This may be due to P-af•AF causing overdrive suppression of the diseased sinus node, leading to more severe sinus arrest after the cessation of P-af•AF. In our experience, pharmacological therapy alone has not been successful in treating SSS, always leaving the possibility of aggravating the condition. In the case of atrial tachyarrhythmias, it is quite common for antiarrhythmic medication to necessitate electrical pacing to counter the overt influence of the drugs. For this reason, determining the presence of atrial tachyarrhythmias is a crucial factor in the treatment of SSS as well.

Pacemaker therapy for SSS after surgery

for ASD

Because the clinical symptoms of SSS after surgery for ASD can vary in severity, and because patients are most often young children, indications for pacing must be based on a careful and thorough examination. Since SSS following surgery can lead to syncope and sudden death^{2,7} and since the prognosis of patients who received pacemakers in this study is quite good, we recommend pacemaker therapy for symptomatic patients, those without adequate escape rhythm, those showing severe abnormalities in EP studies, and particularly for patients with atrial tachyarrhythmias.

Adams-Stokes is an important clinical symptom in postoperative bradyarrhythmias. It was found to occur over a wide range of time postoperatively in both patients with surgical A-V block and patients with SSS after surgery for ASD, thus necessitating careful long-term observation. Postoperative clinical symptoms and prognosis were affected not only by the severity of bradycardia but by tachyarrhythmias as well. Therefore, atrial tachyarrhythmias for patients with SSS, and ventricular tachyarrhythmias for patients with complete A-V block, are important factors that must be considered in the long-term management of bradyarrhythmias following open heart surgery.

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