Association of temporary complete AV block and junctional ectopic tachycardia after surgery for congenital heart disease

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ABSTRACT

Aim : **Junctional ectopic tachycardia (JET) is a postoperative complication with a mortality rate of up to 14% after surgery for congenital heart disease. This study evaluated the risk factors of JET and explored the association of postoperative temporary third degree atrioventricular (AV) block and the occurrence of JET.**

Materials and Methods : **Data were collected retrospectively from 1158 patients who underwent surgery for congenital heart disease.**

Results : **The overall incidence of JET was 2.8%. Temporary third degree AV block occurred in 1.6% of cases. Permanent third degree AV block requiring pacemaker implantation occurred in 1% of cases. In all, 56% of patients with JET had temporary AV block ($P < 0.001$), whereas no case of postoperative JET was reported in patients with permanent AV block ($P = 0.56$). temporary third degree AV block did not suffer from JET.**

Conclusions : **A correlation between temporary third degree AV block and postoperative JET could be observed. The risk factors identified for JET include younger age groups at the time of surgery, longer aortic cross clamping time and surgical procedures in proximity to the AV node.**

Keywords : AV block, congenital heart disease, heart block, junctional ectopic tachycardia

INTRODUCTION

Few data are available about the association of temporary third degree atrioventricular (AV) block and junctional ectopic tachycardia (JET). Postoperative JET is a well-known entity after surgery for congenital heart disease. It causes significant morbidity and has a mortality rate of up to 14%.[1] JET is defined as narrow complex tachycardia with AV dissociation and a ventricular rate exceeding the atrial rate or retrograde 1:1 association.[2] Hemodynamic impairment results from an elevated heart rate during tachycardia in combination with a loss of sequential atrioventricular activation and myocardial impairment shortly after cardiopulmonary bypass.[3]

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The postoperative management of JET often consists of a step-by-step protocol beginning with external pacing for restoration of sequential AV activation over analgia and sedation, followed by the administration of amiodarone for rate control, concluded by hypothermia, which is combined with muscular relaxation in hemodynamically unstable patients.[1] Temporary AVT pacing (atrial pacing following ventricular sensing in a triggered pacemaker mode) as introduced by Janousek *et al.* often improves hemodynamics as the end diastolic ventricular filling by atrial contraction is very important, especially at higher heart rates.[4] Although the exact cause of postoperative JET is still unknown, it is possibly caused by surgical trauma of proximal conduction system mainly by stretch and suture placement.[5] Postoperative third degree AV block is reported with an incidence of 1-3%.[6] It is thought to result from mechanical intraoperative trauma to the conduction system.[7] Up to two-thirds of patients with late onset permanent AV block suffered from postoperative temporary AV block.[8]

Several studies and case reports refer to the causes of congenital JET one of which explores the possible

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association of congenital AV block and JET. These studies outline the importance of AV node or His bundle tissue degeneration for the developement of a congenital JET.[9-12] The origin of AV nodal impairment is obviously different in congenital and postoperative JET. As AV nodal or His bundle tissue impairment occurs in both etiologies, an association of JET and postoperative temporary AV block is plausible. This is the first trial evaluating the association of temporary complete AV block and postoperative JET.

MATERIALS AND METHODS

Data collection

The data of 1158 consecutive patients, who underwent surgery for congenital heart disease, at the University of Leipzig, Heart Center from 2006 to 2010 were studied retrospectively. Following surgery, all patients were admitted to the pediatric intensive care unit. For continuous electrocardiographic and hemodynamic monitoring, portable Siemens SC 9000XC monitors were used. All electrocardiograph (ECG) data were stored automatically.

Patients below the age of 18 years who received open heart surgery and cardiopulmonary bypass were included. Patients without direct opening of either atrial or ventricular myocardium, that is surgery for coarctation of the aorta, Glenn anastomosis or placement of an epicardial pacemaker were excluded. In those patients neither cardiopulmonary bypass is required nor any mechanical influence on the nodal or perinodal tissue takes place. All patient's data were analyzed in respect of the occurrence of temporary or permanent third degree AV block, as well as the occurrence of JET. The JET was defined as narrow complex tachycardia of more than 150 bpm with AV dissociation and a ventricular rate exceeding the atrial rate or retrograde 1:1 association.[2] Whenever JET was suspected, a 12-lead ECG as well as an atrial electrogram via the temporary pacing leads was obtained. Temporary and permanent third degree AV blocks were defined as third degree AV block lasting 7 days or less and permanent AV block was defined as third degree AV block lasting for more than 7 days. ECG`s from one hour after cardiopulmonary bypass to the end of the postoperative hospitalization were included. All postoperative ECGs were re-evaluated by two experienced pediatric cardiologists to confirm the diagnosis. In addition, JET specific therapy (hypothermia, muscle relaxants, amiodarone and pacing) was documented and analyzed. The duration of cardiopulmonary bypass, aortic cross clamping time and minimal body temperature during cardiopulmonary bypass were evaluated. Following surgery, all patients were treated with low to medium doses of inotropes (Milrinone, Dobutamine) for at least one day.

Statistical analysis was carried out with the help a software package called Statistical Package for the Social Sciences (SPSS Version 21.0). Where appropriate, Chi square tests or Fisher's exact tests were used for discrete variables. Relations between JET and supposed risk factor for the occurrence of JET were assessed by logistic regression analyses. Significant variables in univariate analysis were included into a multivariable model. P values < 0.05 were considered statistically significant.

RESULTS

Patients population

The characteristic features of the patients are reported in Table 1. In all, 1158 patients were included. The median age at operation was 2.78 years (0-224 months). There were 53% male patients versus 47% female patients. Age distribution showed a dominance of patients below the age of one year with 58% (n = 674), followed by 22% (n = 261) of patients between 1 and 5 years of age, 11% (n = 124) from 6-10 years of age and 9% (n = 99) of patients with an age of 11-18 years. The in-hospital mortality rate of this study population was 0.17%. There was no JET-associated death.

Overall incidence of AV block and JET

In all, 32 patients with JET, 18 patients (1.6%) with temporary third degree AV block and 12 patients (1%) with permanent third degree AV block were identified [Table 2]. The combination of temporary third degree AV block and JET was observed in 56% (18/32) of patients. There were no patients with permanent AV block and JET (0/32) [Figure 1]. Temporary external pacing was performed on 20 patients with JET. Relaxation was used in 11 patients, amiodarone in 9 patients and therapeutical hypothermia was used in 7 patients [Table 3]. The incidence of surgical closure of ventricular septal defect (alone or in combination with another procedure) and JET was 74.3% (26/32). The AV block was always recognized before the occurrence of

Table 1: Characteristic features of the patients

Patients characteristics	Number of patients
Sex	
Male	615
Female	543
Age at operation	2,78 years (0-224 month)
Cardiac anatomy	
Ventricular septal defect	223
Tetralogy of Fallot / DORV	135
Transposition of the great arteries	114
Atrial septal defect	100
Hypoplastic left heart syndrome	96
Atrio-ventricular septal defect	94
Persistent truncus arteriosus	27
Pulmonary atresia	25
Hypoplastic right heart syndrome	25
Others	319

Table 2: Summary of all patients with a permanent AV block and their individual characteristics and procedural data

Patient	Age at cardiac surgery (years)	Sex	Cross clamping time	Lowest temperature	HLM time	Diagnosis	Secondary diagnosis	Surgical procedure
1	8.6	M	41	30	94	HOCM, SAS,DCRV		Resection of a subaortic membrane, LVOT myectomy, resection of a RV muscular strand
2	0.1	M	51	32	94	VSD	Situs inversus	transtricuspid VSD closure with pericardial patch, 13 single stitch sutures
3	0.2	F	29	22	102	d-TGA,VSD, PS, Tricuspid valve dysplasia		Univentricular palliation with Glenn anastomosis, VSD expansion
4	0.3	M	61	26	103	AVSD (Rastelli type C)	Tri 21	AVSD (2-patch technique), mitral valve reconstruction
5	3.9	F	60	32	103	ASD II, VSD, PHT	Tri 21	ASD, VSD pericardial patch closure with 14 single stitch sutures
6	2.6	F	77	29	120	TOF (DORV type), ASD II		VSD closure with pericardial patch, ASD direct closure
7	0.4	F	60	28	144	AVSD	Tri 21	AVSD (2-patch technique with GoreTex patch)
8	13	F	70	28	144	MS		Re-mitral valve replacement, ATS Mitral Modell 500, 25mm diameter, single stitch U-Tevdek sutures
9	0.5	M	102	24	194	DORV, TGA, non committed VSD	Situs inversus	Rastelli procedure
10	1.1	M	100	14	201	cTGA, PA + VSD		Transmitral VSD closure with single stitches anchored at the RV, ASD II direct closure
11	0.2	F	177	16	344	AVSD (Rastelli type C)	Tri 21	AVSD pericardial patch closure (2-patch technique), mitral valve replacement (aortic valve ATS 16mm "upside down" in mitral position)
12	0	F	159	18	361	Aortic atresia, restrictive VSD, ASDII, CoA		Biventricualr repair, with Norwood I like procedure, Rastelli procedure

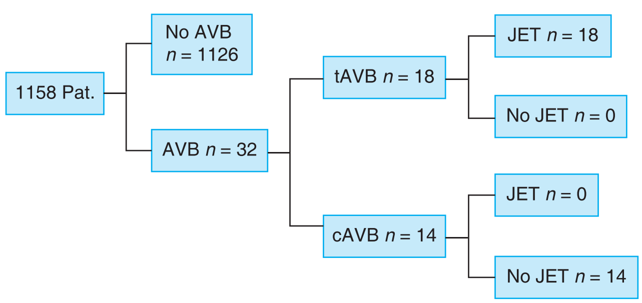

Figure 1: Distribution pattern of temporary or complete AV block and JET

a JET. There were no patients diagnosed with JET who developed a late AV block.

Data analysis

Data analysis showed a highly significant association of JET and postoperative temporary third degree AV block ($P < 0.001$). There were no patients with JET and permanent third degree AV block ($P = 0.56$). However, this result did not reach the level of statistical significance due to the very small number of 14 patients with permanent AV block in contrast to 1144 patients without permanent AV block.

There was a significant correlation of postoperative JET and surgical procedures including closure of ventricular septal defect ($P = 0.001$/OR 4.0 (1.72–9.33)). Analyzing data for further risk factors, showed that a lower age at operation, with a median of 2.9 months in patients with JET and 12.5 months for patients without JET, was a statistically significant risk factor ($P < 0.018$/OR 0.74 (0.58-0.95). In addition, aortic cross clamping time of 63 minutes in patients with JET versus 47 minutes in patients without JET ($P = 0.003$/OR 1.01 (1.01-1.02)) was also identified as a risk factor. Time on cardiopulmonary bypass with 117 minutes in patients with JET versus 91 minutes in patients without JET ($P < 0.16$/OR 1.0 (1.0-0.99)) was not identified as a significant risk factor for the occurrence of postoperative JET. In a multivariable model only aortic cross clamping time ($P < 0.02$) showed statistical significance. As shown in Table 4, no statistically significant association among JET, gender and lowest temperature on cardiopulmonary bypass could be established.

DISCUSSION

This is the first study evaluating the association of temporary AV block after surgery for congenital heart

Table 3: Summary of all patients with JET and their individual characteristics

Patient	Age at JET (month)	Sex	JET	tAVB	Hypothermia	Pacing	Amiodarone	Muscle relaxant	Total number (Hypothermia, Pacing, ...)	Duration AV block (h)
1	0.2	M	Y	Y	Y	Y	Y	Y	4	12
2	0.3	M	Y	Y	Y	Y	Y	Y	4	1
3	0.4	F	Y	Y	Y	Y	Y	Y	4	8
4	1.2	M	Y	N	Y	Y	Y	Y	4	*
5	3.2	F	Y	Y	Y	Y	Y	Y	4	1
6	3.9	F	Y	N	Y	Y	Y	Y	4	*
7	0.2	F	Y	Y	Y	Y	N	Y	3	1
8	1.5	F	Y	Y	N	Y	Y	Y	3	8
9	4.1	F	Y	Y	N	Y	Y	Y	3	1
10	0.5	F	Y	Y	N	Y	N	Y	2	0,5
11	0.7	M	Y	Y	N	Y	N	Y	2	24
12	5.0	F	Y	N	N	Y	Y	N	2	*
13	0.4	F	Y	N	N	Y	N	N	1	*
14	2.4	M	Y	Y	N	Y	N	N	1	72
15	2.6	M	Y	Y	N	Y	N	N	1	6
16	3.0	F	Y	Y	N	Y	N	N	1	8
17	21.5	M	Y	Y	N	Y	N	N	1	60
18	33.9	M	Y	Y	N	Y	N	N	1	48
19	61.4	F	Y	Y	N	Y	N	N	1	48
20	103.7	M	Y	Y	N	Y	N	N	1	0,5
21	0.3	M	Y	N	N	N	N	N	0	*
22	0.8	F	Y	Y	N	N	N	N	0	*
23	1.2	M	Y	N	N	N	N	N	0	*
24	2.3	M	Y	N	N	N	N	N	0	*
25	2.6	M	Y	Y	N	N	N	N	0	*
26	2.8	F	Y	N	N	N	N	N	0	*
27	3.3	M	Y	N	N	N	N	N	0	*
28	3.5	M	Y	N	N	N	N	N	0	*
29	3.6	F	Y	N	N	N	N	N	0	*
30	3.9	F	Y	N	N	N	N	N	0	*
31	10.1	F	Y	N	N	N	N	N	0	*
32	11.6	M	Y	N	N	N	N	N	0	*

N: None, Y: Yes, *: No data available, M: Male, F: Female, tAVB: Temporary third degree AV block

Table 4: Statistical analysis

Variable	Univariate analysis				Multivariate analysis			
	P value	OR	95% Conf. Interv.		*P* value	OR	95% Conf. Interv.	
			lower	upper			lower	upper
Female Sex	.721	1.14	.563	2.30				
Age at operation	.018	.739	.575	.950	.126	.837	.667	1.05
Time on cardiopulmonary bypass (CPB)	.161	1.00	.999	1.00				
Aortic cross clamping time	.003	1.01	1.01	1.02	.020	1.01	1.00	1.02
Minimal temperature on CPB	.390	.961	.877	1.05				
VSD closure	.001	4.00	1.72	9.33	.088	2.39	.878	6.51

disease and the occurrence of postoperative JET. Additionally, risk factors for the occurrence of JET were evaluated in a large cohort and compared to hitherto published data. As outlined before, an association of JET and AV nodal or His bundle tissue degeneration or subtotal tissue damage seems to exist. The mechanism of postoperative JET was hypothesized as being due to regional edema through direct or indirect tissue damage or stretch in the region of hisian tissue with consequent abnormal automaticity.

This assumption is supported by the obvious accumulation of procedures in the region of the AV node and the occurrence of JET. In substance, this applies mostly to procedures with surgical closure of a ventricular septal defect. This was stated by Mildh *et al.* and is consistent with our results.[2]

Interestingly, JET seems to be strictly associated with temporary third degree AV block as in this study not a single JET was diagnosed in a patient with permanent third degree AV block. This may be explained by the fact that permanent third degree AV block is thought to be caused by His bundle or infrahisian tissue damage, whereas temporary third degree AV block is rather due to suprahisian tissue damage. Different effects of damage to suprahisian versus His bundle/infrahisian tissue are routinely demonstrated during slow pathway modulation in the EP laboratory. Induction of thermal injury in the suprahisian region leads to the induction of an accelerated junctional rhythm, whereas if His bundle/infrahisian tissue is affected, a permanent AV block without junctional rhythm occurs. Consequently it seems obvious that local stress during a surgical procedure will produce similar effects.

In Table 3, all patients with JET and their individual therapy are depicted. Therapy is introduced in a step-by-step manner. Patients undergoing combined therapy are affected more severely than those requiring only one therapeutical option. Although the data obtained about the duration of a temporary AV block was incomplete, the last column indicates that shorter the period of temporary third degree AV block, the patient was more affected by JET. This supports the hypothesis that a mild manipulation such as a mere strain of the tissue can trigger this arrhythmia as against severe manipulation with real tissue damage.

As a consequence, perhaps the occurrence of a postoperative permanent third degree AV block is a negative predictive factor of postoperative JET. Similarly, the occurrence of JET in a patient with complete AV block after surgery for congenital heart disease seems to predict the restoration of AV conduction. However, there is insufficient statistical power due to the sample size of this study group. Further studies are needed to verify this assumption.

The presented data confirm some of the hitherto published risk factors for the occurrence of postoperative JET. In substance, younger age at operation and aortic cross clamping time could be verified in this collective study. Previous studies directed by Mildh *et al.* and Hoffman *et al.* included considerably fewer patients than our study. Although both authors' institutions are likely to use slightly different surgical techniques as well as a divergent postoperative management, they report similar findings.[1,2] As an obvious difference, both studies report a higher incidence of JET than the presented study.

It has to be mentioned that our data showed an extraordinarily strong association of JET and temporary third degree AV block. This implicates that all patients who suffered from temporary complete loss of AV conduction developed JET. By means of reason that seems to be somehow overestimated and has never been reported in any other study before. Reasons for this possible overestimation could be the following:

1. Patients with short episodes of temporary complete AV block and without JET were not identified due to suboptimal monitor alarm settings;
2. As the cutoff heart rate of 150 bpm to meet the diagnosis of JET was relatively high compared to other studies some patients with JET at lower heart rates might not have been diagnosed correctly.

Despite these facts, there are arguments supporting the presented results. First of all, the higher heart rate cut off was set to identify primarily hemodynamic relevant tachycardias. In view of the fluent transition to the mostly well tolerated accelerated junctional rhythm, the exact incidence of a clinically relevant JET in the different study collectives is difficult to identify, as we do not know how many of these "slow" JETs were included in other collectives. Secondly, our data implies the occurrence of JET seems to be highly influenced by direct manipulation in the AV nodal region during surgery. Divergent surgical techniques may result in a different incidence of postoperative JET.

Limitations of the study

This was a nonrandomized, retrospective, observational study. The authors cannot exclude the possibility that some arrhythmias might not have been documented in case of unfavorable monitor and alarm settings or failure to recognize JET. Furthermore, the retrospective analysis did not allow to identify the exact doses of catecholaminergic support provided in each individual patient, although these might have an effect on the occurrence of JET.

CONCLUSION

In summary we state that there is a significant association of temporary third degree AV block and postoperative JET. Surgical procedures with proximity to the AV node are a risk factor for postoperative JET. Other predicting factors of JET were young age at operation and longer aortic cross clamping time. Prospective and multicenter data are still lacking and larger systematic surveys are needed.

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