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ORIGINAL ARTICLE

Impact of the operative technique on mid- and long-term results following paediatric heart transplantation

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Abstract

Aims The aim of this study is to evaluate and compare the impact of the bicaval technique versus the biatrial technique (by Lower and Shumway) in paediatric heart transplant patients. Only a few studies investigate this matter regarding the long-term outcome after paediatric heart transplantation. We compared the two surgical methods regarding survival, the necessity of pacemaker implantation.

Methods and results All 134 patients (aged <18 years) – (group-1) biatrial (n = 84), versus (group-2) bicaval (n = 50), who underwent heart transplantation between October 1988 and December 2021, were analysed. Freedom from events were estimated using the Kaplan–Meier method. Potential differences were analysed using the log rank test and Cox proportional hazard models. Mean ± standard deviation: Bypass time (per minutes) was higher in the group 1 as compared with group 2 (P = 0.050). Survival was not significantly different (P = 0.604) in either groups. Eighteen patients required permanent pacemaker implantation in the group 1 and only one patient required it in the group 2 (P = 0.001).

Conclusions Paediatric heart transplantation using bicaval technique results similar long-term survival compared with the biatrial technique. The incidence of atrial rhythm disorders was significantly higher in the biatrial group, requiring a higher frequency of pacemaker implantation in this group. As a results, the bicaval technique has replaced the biatrial technique in our centre.

Keywords Biatrial technique; Bicaval technique; Paediatric heart transplantation

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Introduction

The biatrial technique developed by Lower[1] and Shumway[2] in 1961 has been the gold standard for orthotropic heart transplantation (in adults) for many years. In this technique, the recipient's left and right atria are left in situ and a large atrial anastomosis is used to connect the donor to the recipients' heart.

The bicaval technique was first described in 1991 by Webb et al.[3] In the bicaval technique, the recipient's atria are completely excised, with a small cuff of left atrium remaining around the pulmonary veins, which is then anastomosed to donor's left atrium, followed by direct anastomosis to the venae cavae.

The first paediatric heart transplantation was described by Kantrowitz, who performed the biatrial technique.[4] Some authors published their results in patients with hypoplastic left heart syndrome, also in biatrial technique.[5,6]

In recent years, the biatrial technique was replaced by the bicaval technique. There are however only few reports of the impact of the different surgical techniques in paediatric patients in the published international literature.

In adult's heart transplantation, we detected many published results comparing the two different surgical methods,[7–10] but comparable publications in paediatric heart transplantation are rare.[11]

Therefore, the aim of our study was to detect the rate of complications between the bicaval technique and biatrial techniques in patients under the age of 18, using mortality as our primary outcome variable, and the need for pacemaker implantation as our secondary outcome variable following heart transplantation. We hypothesize that there may be a difference in cardiac arrhythmia between two surgical techniques, which may be of clinical significances.

Methods

Ethical approval statement

This study followed the ethical standards of the Declaration of Helsinki and was approved by the Institutional Review Board of the Ludwig Maximilian University of Munich (LMU) registration's number: 735-15).

Statistics

Data were analysed using SPSS Statistics 28 software (IBM®, Armonk, New York, USA). Continuous variables were expressed as mean ± standard deviation and categorical variables were expressed as frequencies with percentage (percentage) with Student's *t*-test and Wilcoxon test. Differences between means were confirmed using the chi-squared tests. Statistical significance was set at $P < 0.050$. Cumulative survival curves were constructed using the Kaplan–Meier method. A log-rank test was performed to compare survival and necessity of pacemaker implantation after heart transplantation between the groups expending a hazard ratio (HR) using univariable Cox regression analysis.

Study population and study design

All 134 patients (<18 years) who underwent paediatric heart transplantation between October 1988 and December 2021 were included; we analysed 83 patients in group 1 and 50 patients in group 2. The number of paediatric HTXs (heart transplantations) per year and the number of surviving patients at follow up are shown in *Figure 1A,B*.

The criteria and reasons for selecting the two techniques for heart transplants between 2000 and 2013 were depended on surgical skills.

T-test and chi-square analyses were first done to demonstrate that both groups were comparable of demographics and clinical data between 2000 and 2013 (see *Table 1*). These tests have shown that the data of both patient groups are comparable. From 1988 to 1999 (n = 40) the biatrial technique alone was used, from 2000 to 2013 both techniques were used, with the biatrial method (n = 43); and from 2014 to the present only the bicaval (n = 23) technique was applied (see *Figure 1A*). Mean pulmonary vascular resistance was 11 ± 6 Wood units.

For demographics and clinical data of recipients, donors and donor/recipients, see *Table 2*.

In group 1, mean age was 15 ± 16 years, mean BMI was 18 ± 4 per kg/cm^2 and mean follow up time was 15 ± 9 years; in group 2, mean age was 14 ± 12 years, mean BMI was 16 ± 4 per kg/cm^2 and mean follow up time was 7 ± 6 years. The

Figure 1 Biatrial technique versus bicaval technique: Number of heart transplantations (A). Survived patients at follow-up time (B).

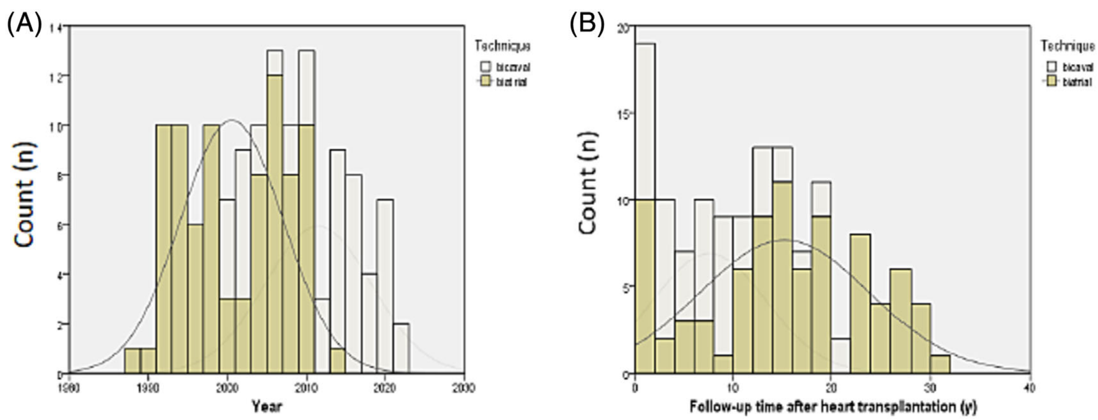

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Table 1 Recipient's demographics and clinical baseline data at time to transplantation from 2000 to 2013 to approve comparability of biatrial- and bicaval-technique

	Mean ± standard deviation (95% CI)		
	Biatrial technique (n = 43)	Bicaval technique (n = 27)	
	n (%)	n (%)	P-value
Age (year)	8.6 ± 6.6	9.6 ± 6.0	0.535
Sex (male), n (%)	22 (51.2)	14 (51.9)	1.000
Body weight (kg)	29.4 ± 22.5	31.9 ± 19.9	0.638
BMI (kg/cm^2)	15.9 ± 3.4	16.8 ± 2.9	0.258
Aetiology (CMP, CHD)	37/6	20/7	0.344
Previous heart operation, n (%)	18 (41.9)	11 (40.7)	1.000
Pre-HTx ECMO (ECLS) Support	3 (7.0)	4 (14.8)	0.417
Pre-HTx VAD support	12 (27.9)	4 (14.8)	0.206

t-test for continuous (numerical) variables. Crosstabs (chi-square) for categorical variables, exact sig. (two-sided).
CI, confidence interval; CMP, cardiomyopathy; CHD, congenital heart disease.

Table 2 Recipient's demographics and clinical baseline data at time to transplantation: standard versus bicaval technique

	Mean ± standard deviation (95% CI)		
	Biatrial technique (n = 83)	Bicaval technique (n = 50)	
	n (%)	n (%)	P-value
Recipient's demographics and clinical baseline data at time to transplantation			
Era			
1988–1999	40 (48)	0	<0.001
2000–2013	43 (52)	27 (54)	
2014–2021	0	23 (46)	
Age (year)	9 ± 7	10 ± 6	0.021
Sex (male)	49 (59)	26 (52)	0.473
Body weight (kg)	29 ± 23	30 ± 20	0.909
BMI (kg/cm^2)	16 ± 4	16 ± 4	0.491
Aetiology			0.279
CMP	62 (75)	42 (84)	
CHD	21 (25)	8 (16)	
Previous heart operation	36 (43)	27 (54)	0.283
ECMO (ECLS) support	6 (7)	8 (16)	0.146
VAD support	15 (18)	20 (40)	0.008
Waiting time on the list (days)	59 ± 47	172 ± 137	<0.001
Donor demographic and clinical baseline data and donor/recipient data			
Age (year)	16 ± 15	14 ± 12	0.687
Body weight (kg)	37 ± 26	37 ± 23	0.489
BMI (kg/cm^2)	19 ± 4	18 ± 5	0.822
Sex (male)	46 (55)	27 (54)	1.000
Cause of death			0.078
Traumatic brain injury	25 (30)	9 (18)	
Cerebral bleeding	10 (12)	5 (10)	
Polytrauma	11 (13)	16 (32)	
Hypoxaemia	12 (14)	6 (12)	
Suicide*	7 (8)	1 (2)	
Other neurological causes	18 (22)	13 (26)	
BMI-(donor/recipient) mismatch	44 (53)	12 (24)	0.002
Hospital timeline			
Aortic cross clamp time (min)	81 ± 27	80 ± 38	0.865
Cold ischaemic time (min)	225 ± 51	237 ± 53	0.218
Bypass-time (min)	149 ± 57	174 ± 88	0.050
Skin-to-skin-time (min)	308 ± 105	345 ± 175	0.178
Length of VS	20 ± 10	37 ± 12	0.013
<72 h	52 (63)	20 (40)	
>72 h	31 (37)	30 (60)	
ICU stay (days)	24 ± 24	52 ± 28	0.498
Hospital-stay after HTx (days)	58 ± 54	57 ± 55	0.995

t-test for continuous (numerical) variables. Crosstabs (Chi-square) for categorical variables, exact sig. (two-sided). BMI mismatch was defined in case of 0.8 > donor/Recipient >1.2; Patient's perioperative data.
CI, confidence interval; CMP, cardiomyopathy; CHD, congenital heart disease; ICU, intensive care unit; VS, length of mechanically ventilation support (h).

follow-up time was ≥1 year post-transplant, and the overall median follow-up time was 13 years.[6–19]

The following patients were excluded: one patient after pHTx was lost to follow-up, heart and lung transplantation, ABO-incompatible heart transplantation, combined heart and liver or heart and kidney transplantation and re-transplantation after primary heart transplantation in paediatric patients. Patient's data are included and studied in this actual study until re-HTx time.

Treatment

Standard Stanford triple immunosuppressive therapy was used in both groups.[12,13]

Results

Overall median (IQR) follow-up time (years) was 13.1 (5.6–19.0). Median follow-up time (IQR) was in group 1: 15.7 years (10.2–22.7), and in group 2, it was 8.1 years (3.2–8.1) (see *Figure 1B*).

Primary outcome: Survival

See *Table 2* and *Figure 2* for Kaplan–Maier-curve: Cumulative survival (%) after paediatric heart transplantation in years.

In group 1, survival at 30 days, 1, 5, 10, 15 years was 96 ± 2%, 89 ± 3%, 83 ± 4%, 79 ± 4% and 66 ± 5%, and in group 2, 96 ± 3%, 94 ± 3%, 87 ± 4%, 74 ± 8% and 48 ± 13% (P = 0.604).

Secondary outcome: Pacemaker implantation

Thirty per cent of patients in group 1 (n = 18) required permanent pacemaker implantation. This was significantly higher than those in group 2 patients (P = 0.001); see *Figure 3* and *Table 3*.

Features and results in patients with permanent pacemaker implantation

Overall mean time to require a pacemaker implantation was 1700 ± 1745 (days) (see *Figure 3*).

In group 1, six patients required a pacemaker implantation in the first 180 days after the HTx. Twelve patients underwent pacemaker implantation between 2 to 10 years post-transplant. Mean time interval between HTx and time to requiring a permanent pacemaker implantation was 1698 ± 1736 (days). Eight patients died in mean the time 14 ± 10 years post-transplant. Three patients underwent re-transplant because of graft failure from 5 to 12 years after their primary HTx. Congenital heart disease with hypoplastic left heart syndrome in end-stage heart failure was shown in three of patients. Four patients underwent an ECMO/ECLS support after

Figure 2 Kaplan–Meier curve, cumulative survival (%) after paediatric heart transplantation (years).

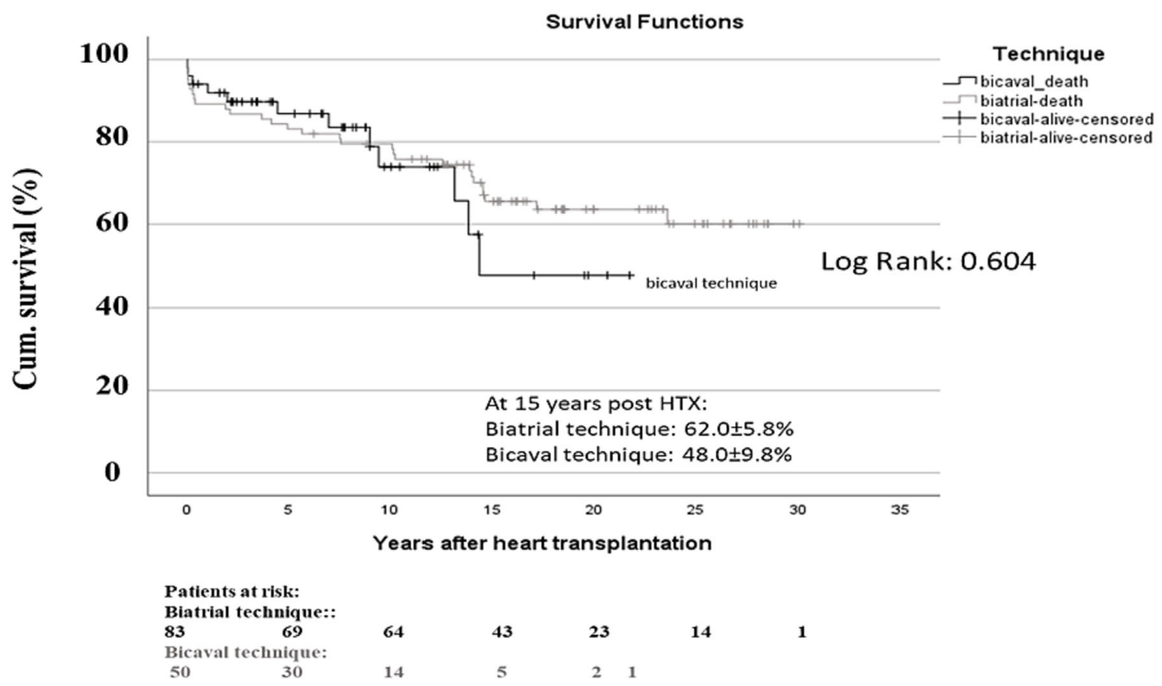

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Figure 3 Kaplan–Meier curve, cumulative freedom of pacemaker implantation after paediatric heart transplantation (%).

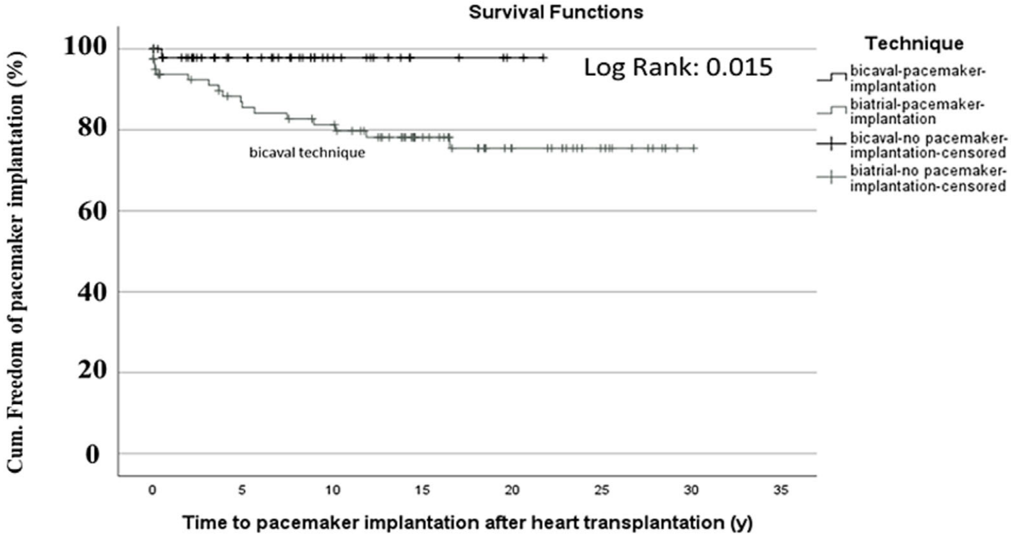

Table 3 Long-term outcomes

	Mean ± standard deviation (95% CI)		
	Biatrial technique (*n* = 83)	Bicaval technique (*n* = 50)	
	n (%)	*n* (%)	*P*-value
Follow up (years)	15 ± 9	7 ± 6	0.007
Post-HTx ECLS	12	11	0.344
Tricuspid valve regurgitation early post-HTx	21 (24)	17 (34)	0.554
Mild	11 (13)	6 (12)	
Moderate	3 (4)	9 (18)	
Severe	7 (8)	2 (4)	
Tricuspid valve regurgitation at last follow- up	14 (17)	19 (42.2)	0.078
Mild	6 (72)	8 (16)	
Moderate	3 (4)	7 (14)	
Severe	5 (6)	1 (2)	
Post-HTx cardiac arrhythmia	45 (54)	22 (44)	0.286
Sinus node arrest	33 (40)	16 (32)	
AV block	12 (14)	6 (12)	
Post-HTx pacemaker implantation	18 (23)	1 (2)	0.001
Time to pacemaker Implantation (days)	1689 ± 1755	171	
Post-HTx bleeding	33 (40)	17 (34)	0.581
Post-HTx effusion	29 (35)	15 (30)	0.575
Post-HTx re-sternotomy	13 (16)	11 (22)	0.486
Cause of death after HTx[a]	29 (35)	12 (24)	0.693
Early/primary graft failure	25 (30)	10 (20)	
Acute severe rejection	1 (1)	1 (2)	
Acute severe humoral rejection reaction	3 (6)	2 (4)	
TVP	18 (22)	7 (14)	
PTLD	1 (1)	3 (6)	
Respiratory failure	0	1 (2)	
Renal failure	1 (1)	2 (4)	
Tumour	1 (1)	2 (4)	
Late graft failure	5 (6)	2 (4)	
Multi organ failure	1 (1)	1 (2)	
Bleeding	1 (1)	0	
Infection	21 (25)	7 (14)	
Non cardiac	3 (4)	0	

t-test for continuous (numerical) variables. Crosstabs (chi-square) for categorical variables, exact sig. (two-sided).
CI, confidence interval.
[a]One or more reasons to death at mortality time.

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the transplantation. Six patients needed dialysis treatment for 4 months after the transplantation. Two of the 6 are still on dialysis treatment. Transplant vasculopathy was detected in 15 patients, in four of them was shown a CMV positive mismatch between recipient and donor and in two patients of them needed a coronary artery bypass graft. Ten patients developed chronic rejection. Gender mismatch between recipient and donor was also shown in 10 patients, BMI mismatch between recipient and donor (0.8 $>$ donor/recipient $>$1.2) was detected in nine patients.

Post-HTx diabetes mellitus developed five patients after their heart transplantation.

In group 2, the only patient who underwent a pacemaker implantation after 6 months post-transplant died at 4.4 years post-heart transplantation because of intracerebral post-transplant lymphadenopathy disorder.

Overall results

The mean skin-to-skin time (min) in group 1 was 308 ± 105 and in group 2 was 345 ± 175 (P = 0.367). The mean aortic cross-clamp time (min) in group 1 was 81 ± 27 and in group 2 was 80 ± 38 (P = 0.865). Mean total cold ischaemic time (min) in group 1 was 225 ± 51 and in group 2 was 237 ± 53 (P = 0.218). Mean ICU stay (days) in group 1 was 24 ± 24 and in group 2 was 52 ± 28 (P = 0.498). Mean hospital stay after HTx (days) in group 1 was 58 ± 54 days and in group 2 was 57 ± 55 days (P = 0.995).

Patients in the group 1 were younger (P = 0.033). BMI – mismatch (0.8 $>$ donor/Recipient $>$1.2) was higher in the group 1. VAD-support bridged to HTx was higher in the group 2 (P = 0.008) because of elongated waiting time on the list ($P < 0.001$).

In univariate Cox analysis, the following were significant risk factors for overall mortality: lower BMI (per kg/cm^2; OR: 1.081; 95% CI: 1.016–1.149; P = 0.013); greater bypass time (per minutes; OR: 1.005; 95% CI: 1.000–1.010; P = 0.041); greater skin-to-skin time (per OR: 1.005; 95% CI: 1.002–1.008; P = 0.003); presence of tricuspid valve regurgitation directly after transplantation (OR: 2.901; 95% CI: 1.561–5.391; $P < 0.001$) and at the last follow-up: (OR: 2.841; 95% CI: 1.156–6.983; P = 0.023) (see *Table 4*).

Table 4 Risk factor analysis for mortality: Univariable Cox analysis and multivariable Cox analysis

	Univariable Cox analysis for overall mortality			Multivariable Cox analysis for overall mortality		
	OR	95% CI	P-value	OR	95% CI	P-value
Recipient feature						
Waiting on the list (days)	1.000	0.997–1.003	0.818			
Age (per years)	1.034	0.986–1.085	0.168			
Sex (male)	1.129	0.610–2.090	0.699			
Aetiology	1.491	0.771–2.885	0.235			
SV physiology	1.583	0.775–3.234	0.207			
Body weight (per kg)	1.012	0.999–1.026	0.074			
BMI (per kg/cm^2)	1.10.5	1.020–1.196	0.014	1.151	1.055–1.257	0.002
Previous heart operation	1.363	0.737–2.521	0.324			
Pre-HTx ECLS/ECMO	1.814	0.758–4.341	0.181			
Pre-HTx VAD Support	0.711	0.296–1.706	0.444			
Donor feature						
Age (per years)	1.017	0.998–1.036	0.076			
Sex (male)	0.902	0.484–1.680	0.744			
Body weight (per kg)	1.011	0.998–1.023	0.092			
BMI (per kg/cm^2)	1.081	1.016–1.149	0.013			
Donor/recipient feature						
Mismatch in BMI donor/recipient	1.234	0.663–2.296	0.506			
Mismatch in sex donor/recipient	0.859	0.463–1.593	0.630			
Intraoperative data						
Cold ischaemic time (per min)	0.831	0.412–1.674	0.604			
Aortic clamp time (per min)	1.009	1.000–1.019	0.051			
Bypass time (per min)	1.005	1.000–1.010	0.041	1.005	1.002–1.009	0.006
Skin-to-skin-time (per min)	1.005	1.002–1.008	0.003			
Early/primary graft failure	1.000	0.510–1.961	1.000			
Late graft failure	0.854	0.462–1.581	0.616			
Post-HTx ECLS	1.776	0.870–3.627	0.115			
Post-HTx bleeding	0.936	0.499–1.755	0.837			
Re-sternotomy	1.417	0.676–2.969	0.356			
Post-HTx cardiac arrhythmia	0.658	0.355–1.220	0.183			
Post-HTx pacemaker implantation	1.351	0.623–2.927	0.446			
Post-HTx tricuspid regurgitation						
At post-op time	2.901	1.561–5.391	<0.001			
At follow up time	2.841	1.156–6.983	0.023			

Risk factor analysis for mortality in chi-square test.
CI, confidence interval; BMI, body mass index; OR: odd ratio.

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In the multivariable Cox analysis, lower BMI (per kg/cm^2, OR: 1.151; 95% CI 1.055–1.257; P = 0.002), and greater bypass time were significant risk factors (per minutes; OR: 1.005; 95% CI: 1.002–1.009; P = 0.006) for overall mortality (see *Table 4*).

Cardiac arrhythmia after transplantation was observed in 54% of cases in group 1 (n = 45) versus 44% (n = 22) in group 2 (P = *0.286*) (see *Table 3*).

Most post-transplant arrhythmia were normalized at discharge time. Pacemaker implantation was performed in 18 patients in group 1 and in one patient in group 2 (P = 0.001).

Tricuspid valve regurgitation was observed in both groups after transplantation (21 patients in the group 1 and 17 patients in the group 2), but it normalized by time of discharge (P = 0.554) (see *Table 3*).

Discussion

Survival

In our centre, the bicaval technique has only been performed since May 2000, limiting the number of patients in this group (group 1).

Survival of paediatric patients after bicaval technique was comparable to those after the biatrial technique at our centre. Based on improved survival rates, Davies et al. recommend that a bicaval anastomoses should be performed for heart transplantation, except where technical considerations require a biatrial technique.[14] In a meta-analysis, the authors showed significant valuable effects of the bicaval technique with regard to survival.[15] In addition, bicaval technique is technically easier to perform under this circumstance further facilitates cardiac transplantation. This technique is also suitable for performing even in complex congenital heart disease with persistent left superior vena cava.[16] Furthermore, a biatrial technique remains as gold standard technique for patients with heterotaxy syndrome.[17]

In addition, haemodynamic variables such as pulmonary capillary pressure, mean pulmonary artery pressure, and right atrial pressure are reported lower after bicaval transplantation.[18] Therefore, the bicaval technique has now become more popular than the biatrial technique.[19,20] A systematic review with meta-analysis showed that results after bicaval heart transplantation are better in early- and late-term outcomes than after biatrial technique in adults.[21] Four-corner traction bicaval anastomosis combined with a continuous everting suture technique may result in approximately comparable survival after HTx in patients with a history of previous cardiac surgery when compared with those without. This technique might reduce the incidence of left atrial thrombosis and distortion. Further follow-up of long-term outcomes is required to validate these results.[22]

Arrhythmia

We could not identify any literature on the topic of the risk of arrhythmias after transplantation in the paediatric transplant population. A better anatomic configuration and synchronous atrial function after the bicaval method may well have contributed to the normal rhythm and reduced need for pacemaker implantation.[23]

In patients with the bicaval technique, we detected a lower rate of development of bradyarrhythmias resulting in a lower frequency for permanent pacemaker implantation. Pacemaker implantation because of bradyarrhythmia after cardiac transplantation is common, and has no risk of sudden cardiac death. The bicaval surgical technique was strongly protective against postoperative pacemaker requirement in pacemaker-requiring bradyarrhythmia with an excellent long-term prognosis in adults. Biatrial surgery was associated with postoperative pacemaker requirement.[24] Grant et al. showed a significant increase in the incidence of atrial tachyarrhythmia in patients with biatrial technique and a higher hospital stay in this group.[25]

The significant reduction in pacemaker implantation in the bicaval group is most likely due to the surgical trauma to the right atrial tissue in biatrial implantation technique. Of note, the biatrial implantation technique requires cranial to caudal incision of the lateral right atrial wall along the level of the *linea arcuata* and hence endangers the regular conduction, when the incision is carried out too far cranially. In addition, there is considerable traction on the right atrial tissue after biatrial implantation as the new lateral opening in the donor organ should cover the ventral aspect of the remnant recipient right atrium. The distinct abnormal placement of the donor heart in biatrial implantation predisposes to tricuspid regurgitation.

Duration of hospital stay after heart transplantation did not differ between the groups in our results (P = 0.321); sinus node arrest and atrioventricular block were higher in group 1 but without significance (P = 0.286). We did not detect any supraventricular tachycardia like atrioventricular nodal reentry tachycardia (AVNRT) after paediatric transplantation. In adult patients radiofrequency catheter ablation can eliminate this kind of atrial tachycardia and resulting in haemodynamic improvement.[26,27] In our study pacemaker, implantation was mostly necessary in the first year after transplantation.

A relationship between post-transplant vasculopathy (TVP) and late necessity of pacemaker implantation in our collective was comparable to international results.[28,29]

Other effects

Some authors reported a shorter duration of hospital stay in relation to the surgical technique.[30] In our experience, the hospital stay before HTx in the group 2 was slightly higher because of increasing waiting times on the list in the past decade. After heart transplantation, the length of hospital-stay did not differ between the groups. A single large-scale experience in adults with bicaval versus biatrial technique for heart transplantation found no difference in survival between the two groups, although the bicaval technique was associated with a lower incidence for permanent pacemaker implantation.[31] Grande et al. showed significantly less bleeding and fewer surgery-related complications, fewer major arrhythmias and less need for pacemaker implantation after bicaval HTx in their study.[10] Another study highlights the importance of preference of the bicaval technique for orthotropic heart transplantation, especially in selected young patients with low BMI and, in particular, those potential transplant recipients with end-stage cardiac disease in patients with congenital heart disease.[32]

Tricuspid valve regurgitation

Tricuspid valve regurgitation (TVR) is a common complication after heart transplantation.[33,34] The bicaval technique maintains good left ventricular function, a lower incidence of tricuspid valve dysfunction, and improved survival compared to the standard technique in adult patients.[8,32,35] Only few authors described that no significant difference was observed between the rate of TVR of biatrial and bicaval anastomosis in patients at different time points.[36] In our opinion, the causes of TVR following transplantation are multifactorial, with surgical technique being an important factor. In our collective, there was no significant difference in early- and long-term results in both groups (see *Table 3*).

We are aware that TVR can be caused through injury during myocardial biopsy with the bioptome passing across the tricuspid valve ring.[34,37] Therefore, it can be induced over time due to a higher frequency of endomyocardial biopsies in the context of the post-transplant monitoring. In our centre, the use of rejection monitoring with biopsy has decreased in recent years. Therefore, this might be one reason why there is no difference of the development of TVR between both surgical technique groups. In addition, distortion of the tricuspid valve ring due to size mismatch between the donor and recipient seems not to be a problem in the studied population.[8]

Summary

Many publications have demonstrated that the bicaval surgical technique is superior to the biatrial technique in the adult transplantation group. There are many reasons for this. One of them may well be that it is easier to perform and there are less atrial arrhythmias reported after the bicaval technique in adults. In our cohort there was a significant reduction of the incidence of atrial arrhythmia using the bicaval technique compared with the biatrial technique. We conclude that the bicaval surgical technique in the paediatric transplant population has the advantage of reducing the need for pacemaker implantation.

Regarding the overall survival, the results we achieved after bicaval technique are comparable with those of the biatrial technique. Neither technique appears to offer a surgical benefit over the other.

The biatrial technique may be still necessary to perform transplantation in very rare and complex heart failure patients, for example, patients with heterotaxy syndrome/with or without dextrocardia. Based on the lower complication rate, the bicaval technique has been the preferred surgical procedure for paediatric heart transplantation in our centre since 2013.

One limitation of the current study is the small sample size in both groups. Another is the short follow-up time, particularly in the bicaval group due to the recent implementation of this surgical technique. Finally, one possible limitation of this study is the failure to account for differences in immunosuppressive regimens between groups and its potential effect on treatment outcomes.

Our results are comparable with international results.[37,38]

Conclusions

Paediatric heart transplantation performed by the bicaval technique yields similar long-term survival compared to the biatrial technique. In the biatrial group, the incidence of atrial rhythm disorders was significantly higher. The incidence of pacemaker implantation was significantly higher following the biatrial technique (group 1). Based on these results, the bicaval technique has replaced the biatrial standard technique in our centre.

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Conflict of interest

There is no conflict of interest for any of the authors regarding this report.

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