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Surgical outcome of Yasui procedure for preserving biventricular function: single centre experience

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Abstract

Background: Yasui procedure is surgical repair intended to preserve biventricular function for patients with left ventricle outflow tract obstruction associated with aortic arch lesions and ventricular septal defect. *Methods*: Retrospective chart review analysis of all patients who had Yasui procedure (2008–2020) comparing midterm outcome of one versus two stage repair. *Results*: Twenty patients (70% female) underwent Yasui procedure in our center. Eight patients (40%) had left ventricle outflow tract obstruction /interrupted aortic arch, 7 patients (35%) had left ventricle outflow tract obstruction /coarctation of aorta, 3 patients (15%) had double outlet ventricle and ventricular septal defect that were unattainable for tunneling to one of the semilunar valves without creating obstruction, and 2 patients (10%) had aortic atresia with hypoplastic aortic arch. All patients had associated ventricular septal defect. Fifteen patients (75%) had one-stage repair and 5 patients (25%) had two-stage repair. Means age and weight for one and two-stage repair were 1.3 ± 2 months, 13.4 ± 11.5 months and 3.3 ± 0.6 kg, 7.8 ± 3.4 kg, respectively. During follow up, 8 patients (40%) required re- intervention, mainly for right ventricle–pulmonary artery conduit either dilation or replacement. The average duration of follow up was 5 years with nil mortality. *Conclusion*: Yasui procedure is effective approach for children who have left ventricle outflow tract obstruction associated with aortic arch anomalies and ventricular septal defect. Survival rate with single or staged repair is comparably good. During the first 5 year of follow up, nearly 40% of operated patients required re-intervention.

Yasui procedure is a complex and extensive operation that was first described by Yasui and his colleagues in 1987 on two patients with left ventricle outflow tract obstruction/interrupted aortic arch.[1] It has been also performed for patients with severe aortic stenosis/aortic atresia, hypoplastic or interrupted aortic arch and a well-developed apex-forming left ventricle.[2] Yasui procedure constitutes of combination of integrated aortic arch reconstruction, redirection of left ventricle outflow through ventricular septal defect to both semilunar valves and establishment of right ventricle–pulmonary artery connection.[3] It can be done as one-stage versus two-stage repair that includes initial modified Norwood procedure followed by Rastelli-type repair.[4–9] Unlike the single ventricle pathway, Yasui procedure has the advantage of biventricular repair that results in normal serial pulmonary systemic circulation (Qp:Qs = 1:1) with normal saturated blood being ejected in the systemic circulation.[2] The overall results of Yasui procedure have been variable with reported operative mortality of 6.7%,[2] and actuarial 10-year survival ranging between 78%[8] and 87.8%.[3] The aim of our study is to describe our experience with Yasui procedure in the current era comparing the overall outcome between patients who had one-stage versus two-stage repair, the need for reintervention and associated major morbidity and mortality.

Materials and methods

We conducted a retrospective study that was approved by institutional review board. We reviewed electronic data and medical charts for all the patients who had Yasui procedure in our center from 2008 to 2020. We divided the patients into two groups, those who had one-stage repair (complete Yasui procedure) and two-stage repair (either Norwood procedure then Rastelli-type repair or aortic arch repair and PA band followed by Yasui procedure, or aortic arch repair then Yasui procedure). We performed statistical analysis for both groups and compared peri-operative characteristics. We determined the need for reintervention by

Table 1.

Variable	One-stage repair group, n = 15	Two-stage repair group, n = 5	p value
Gender			
Female	11 (73.3%)	3 (60%)	
Age at surgery (months)	1.3 ± 2	13.4 ± 11.5	
Weight at surgery (kg)	3.3 ± 0.6	7.8 ± 3.4	
Diagnosis			
LVOTO/IAA	6 (40%)	2 (40%)	1
LVOTO/CoA	6 (40%)	1 (20%)	0.61
AA/hypoplastic aortic arch	2 (13.3%)		
Double outlet ventricle	1 (6.7%)	2 (40%)	0.14
DORV		2	
DOLV	1		
Type of associated VSD			
Outlet muscular	14 (93.3%)	3 (60%)	0.14
Outlet perimembranous	1 (6.7%)		
Doubly committed		1 (20%)	
Non committed		1 (20%)	
Associated syndrome			
DiGeorge	1 (6.7%)		
CHARGE association	1 (6.7%)		

Patients' demographic characteristics for one-stage and two-stage repair groups. AA: aortic atresia, CoA: coarctation of aorta, DOLV: double outlet left ventricle, DORV: double outlet right ventricle, IAA: interrupted aortic arch, Kg: kilogram, LVOTO: left ventricular outflow tract obstruction, VSD: ventricular septal defect.

catheterisation or surgery, presence of residual lesions and mid-term outcome of all patients including mortality rate.

Results

During the study period, 20 patients had Yasui procedure. Table 1 demonstrate Patient's characteristics. Eight patients (40%) had left ventricle outflow tract obstruction /interrupted aortic arch, seven patients (35%) had left ventricle outflow tract obstruction/coarctation of aorta, three patients (15%) had double outlet ventricle (two double outlet right ventricle, one double outlet left ventricle), two patients (10%) had aortic atresia with hypoplastic aortic arch. Table 2 demonstrates patient's cardiac and echocardiographic characteristics. Table 3 demonstrate operation characteristics in both groups. Two-stage repair was achieved using Norwood procedure followed by Rastelli-type repair in two patients, aortic arch repair and pulmonary artery band then Yasui procedure in two patients and one patient had aortic arch repair then Yasui procedure. In double outlet right ventricle and double outlet left ventricle patients, tunneling ventricular septal defect to one of the semilunar valves was unattainable without creating obstruction, for this reason patients underwent Yasui procedure (Dammus-Kaye-Stansel + Rastelli-type repair).

There was neither peri-operative mortality nor inter-stage death. Two patients of one-stage repair group needed permanent pacemaker insertion for post-operative complete heart block. None of the patients needed extracorporeal membrane oxygenation post-operatively.

The average time of follow-up was 5 years (range: 0.4–10.4 years). Eight out of 20 patients (40%) needed either surgical or catheter re-intervention. Figure 1 demonstrates characteristics of patients who required re-intervention and types of reinterventions needed. The average times for catheter and surgical re-intervention were 1.5 years (0.02–2.8 years) and 3.9 years (1.1–7.4 years), respectively. There was no statistical difference between one and two-stage repair groups in term of re-intervention need.

Discussion

Yasui procedure is recommended for patients with aortic stenosis/hypoplasia or left ventricle outflow tract obstruction associated with ventricular septal defect in whom a simple repair might not be enough to accommodate cardiac output. Kanter et al,[10] applied Yasui procedure when the minimum diameter of left ventricle outflow tract (at the aortic valve or below) is less than 4 mm. Nakano et al,[3] considered Yasui procedure when the minimum left ventricle outflow tract diameter is ≤(body weight + 1 mm). All our patients followed Nakano rule for Yasui procedure.

Early study of Yasui procedure was by Ohye et al[8] who reported 20 patients underwent Yasui procedure (11 patients had one-stage repair and 9 patients had staged repair), actuarial survival for the entire group was 78 ± 10% at 5 years with no difference between one-stage repair (73%) versus staged repair (89%). Another study by Kanter et al[10] reported 21 patients who underwent Yasui procedure (15 patients had staged repair and 6 patients had one-stage repair), there was no early mortality, actuarial survival after initial repair was 100% at 1 year and 75% at 5 years. In more recent study by Nakano et al[3] who reported their

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Table 2.

	Cardiac diagnosis				Echocardiographic characteristics						
No	LVOT anatomy	Arch anatomy	Cardiac anatomy	Aberrant RSCA	LVOT diameter (mm)	AoV annulus diameter (mm)	AoV annular diameter z score	Indexed aortic root diameter (cm/m^2)	Indexed MV area (cm^2/m^2)	LAR	Associated syndrome
1	LVOTO	IAA-B	Outlet VSD	Yes	3.4	3.5	−5.64	3	5.4	1	DiGeorge syndrome
2	LVOTO	IAA-B	Outlet VSD		3	3	−10.18	3	6.8	0.96	
3	LVOTO	IAA-B	Outlet VSD		3	3	−7.1	3.46	6.8	0.93	
4	LVOTO	IAA-B	Outlet PM VSD	Yes	3	3.6	−6.61	2.04	4.9	0.93	CHARGE association
5	LVOTO	IAA-B	Outlet VSD		3.5	5	−8.28	2.7	6.7	0.93	
6	LVOTO	IAA-B	Outlet VSD		4.5	5	−2.93	3.4	8.2	0.97	
7	LVOTO	IAA-B	Outlet VSD		4	4	−5.94	3.3	7	0.92	
8	LVOTO	IAA-C	Outlet VSD		3	4	−5.32	2.8	4	0.96	
9	LVOTO	CoA	Outlet VSD		3.3	4	−5.48	2.95	4.3	0.9	
10	LVOTO	CoA	Outlet VSD		4	4	−5.2	3	5.5	1	
11	LVOTO	CoA	Outlet VSD		4	5.5	−2.2	4.2	6.7	0.96	
12	LVOTO	CoA	Outlet VSD		3.8	3.8	−5.44	2.1	4.5	0.96	
13	LVOTO	CoA	Outlet VSD		4	4	−5.51	3.7	6.4	0.97	
14	LVOTO	CoA	Outlet VSD		3.6	3.6	−7.16	3.1	4	0.96	
15	LVOTO	CoA	Outlet VSD		3	3	−8.04	2.4	4.7	0.96	
16	Aortic atresia	Hypoplastic aortic arch	Outlet VSD						4.5	0.96	
17	Aortic atresia	Hypoplastic aortic arch	Outlet VSD	Yes					7.5	0.92	
18		IAA-A	DORV, non-committed VSD			12	1.5		5.3	0.9	
19		CoA	DORV, doubly committed VSD			8	−0.22		7.8	0.96	
20			DOLV, outlet VSD			15	6.95		12.2	0.92	
Mean ± SD					3.54 ± 0.49* mm	3.9 ± 0.7* mm	−6 ± 1.9 *	3 ± 0.57*	6.2 ± 1.9	0.94 ± 0.02	

Cardiac and echocardiographic characteristics of all 20 patients who had Yasui procedure. AoV: aortic valve, CoA: coarctation of aorta, DOLV: double outlet left ventricle, DORV: double outlet right ventricle, IAA: interrupted aortic arch, LAR: the ratio of the long axis of the left ventricle to that of the heart, LVOT: left ventricular outflow tract, LVOTO: left ventricular outflow tract obstruction, MV: mitral valve, PM: perimembranous, RSCA: right subclavian artery, VSD: ventricular septal defect.
*AA, DORV and DOLV patients were not included in calculating the mean.

Table 3.

Variables	One-stage repair group, n = 15	Two-stage repair group, n = 5	p value
CPB time (minutes)	164.1 ± 53.3	163.5 ± 55.8	0.98
Aortic arch reconstruction method			
Homograft	12 (85.7%)	1 (20%)	
Contegra patch	2 (14.3%)		
Extended end to end anastomosis		4 (80%)	
Interventricular routing			
Tunneling VSD to DKS	15 (100%)	5 (100%)	
RV-PA connection			
Contegra conduit	14 (93%)	5 (100%)	
Homograft	1 (7%)		
Hospital course			
Mean extubation time (days)	19.8 ± 30.6	3.3 ± 3.2	0.38
Mean ICU stay (days)	29.9 ± 23.4	8.6 ± 4.5	0.15
Mean hospital stay (days)	49 ± 38.4	14 ± 2	0.14
Post-operative complication	7 (46.6%)	1 (20%)	0.6

Operation characteristics and comparison between one-stage and two-stage repair groups. CHB: complete heart block, CPB: cardiopulmonary bypass, DKS: Dammus-Kaye-Stansel, ICU: intensive care unit, RV-PA: right ventricle to pulmonary artery, VSD: ventricular septal defect.

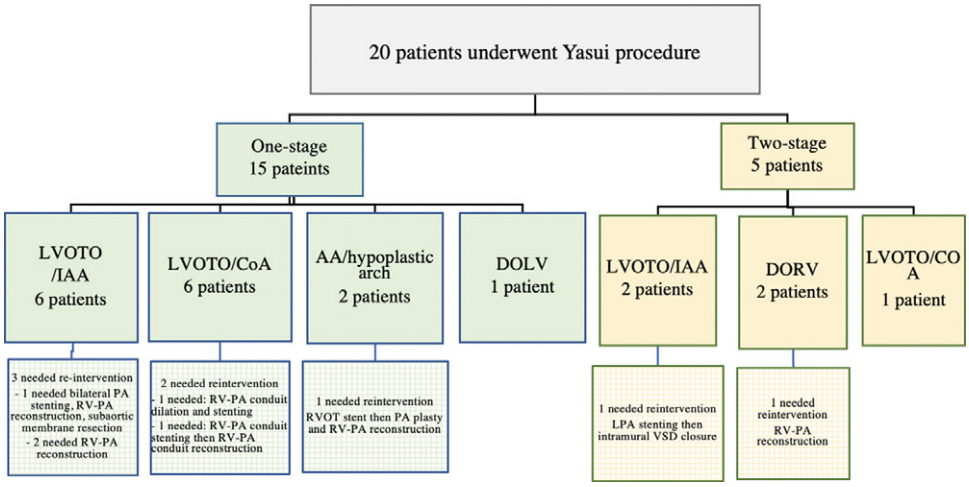

Figure 1. Details of 20 patient who underwent Yasui procedure including those with one or two-stage repair. The figure also demonstrates cases who needed reinterventions and the details of reintervention in each group. AA: aortic atresia, CoA: coarctation of aorta, DOLV: double outlet left ventricle, DORV: double outlet right ventricle, IAA: Interrupted aortic arch, LPA: left pulmonary artery, LVOTO: left ventricular outflow tract obstruction. PA: pulmonary artery, RVOT: right ventricular outflow tract, RV-PA: right ventricle – pulmonary artery, VSD: ventricular septal defect.

experience of Yasui procedure in 17 patients who underwent Yasui procedure (6 patients had one-stage repair and 11 patients had staged repair), there was only one early death, with actuarial survival at 10 years of 87.8%. Our study showed comparable results with no mortality and average follow up duration of 5 years (range: 0.4–10.4 years).

In comparison of one stage repair versus two stage repair, Nakano et al[3] reported one operative death in one-stage repair group and one late death (non-cardiac) in staged repair group, more stable postoperative course in staged repair group, and similar incidence of reoperation. Kanter et al[10] reported comparable rates of mortality and reoperation between one-stage and two-stage repair groups. Similarly, Ohye et al[8] found no significant difference in survival rate between one-stage and staged repair groups. Gruber et al[11] reported 21 patients underwent one-stage Yasui procedure with 100% in-hospital survival, 1 late death and 11 patients had interventricular baffle leak, 4 of them needed reintervention. In our study, one-stage and two-stage repair were statistically indifferent in terms of complications rate and re-intervention need. However, we encountered post-operative complete heart block in two patients among one-stage group patients who needed permanent pacemaker implantation.

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Our study had many limitations including single centre experience, small number of patients, and medium duration follow up.

Conclusion

Yasui procedure is excellent approach to preserve biventricular function in left ventricle outflow tract obstruction associated with aortic arch lesions and ventricular septal defect. Survival rates for both one and two stage approach were comparable. Re-intervention is unavoidable, and it is needed in almost of 40% of patients within 5 years post initial repair, mainly for right ventricle – pulmonary artery reconstruction.

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Conflicts of interest. None.

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