

Outcomes of Norwood procedure with hypoplastic left heart syndrome: Our 12-year single-center experience

Hipoplastik sol kalp sendromunda Norwood işleminin sonuçları: 12 yıllık tek merkezli deneyimimiz

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ABSTRACT

Background: In this study, we aimed to analyze the predictors and risk factors of mortality in patients who underwent Norwood I procedure with the diagnosis of hypoplastic left heart syndrome.

Methods: Between January 2009 and December 2020, a total of 139 patients (95 males, 44 females) who underwent Norwood I procedure with the diagnosis of hypoplastic left heart syndrome in our center were retrospectively analyzed.

Results: The median birth weight was 3,200 (range, 3,000 to 3,350) g and the median age at the time of operation was seven (range, 5 to 10) days. Pulmonary flow was achieved with a Sano shunt in the majority (72%) of patients. Survival rate was 41% after the first stage. Reoperation for bleeding (p=0.017), reoperation for residual lesion (p=0.011), and postoperative peak lactate level (p=0.029), were associated with in-hospital mortality. Nineteen (33%) of 57 patients died before the second stage. Thirty-three (58%) patients underwent second stage, and survival after the second stage was 94%. Thirteen patients underwent third stage, and survival after the third stage was 85%. Estimated probability of survival at six months, and one, two, three, and four years were 33%, 33%, 25%, 25%, and 22% respectively.

Conclusion: Hospital and inter-stage mortality rates are still high and this seems to be the most challenging period in term of survival efforts of the patients with hypoplastic left heart syndrome. Early recognition and reintervention of anatomical residual defects, close follow-up in the inter-stage period, and the accumulation of multidisciplinary experience may help to improve the results to acceptable limits.

Keywords: Hypoplastic left heart syndrome, inter-stage mortality, Norwood procedure.

ÖZ

Amaç: Bu çalışmada, hipoplastik sol kalp sendromu tanısıyla Norwood I işlemi uygulanan hastalarda mortalitenin öngörücüleri ve risk faktörleri incelendi.

Çalışma planı: Ocak 2009 ve Aralık 2020 tarihleri arasında merkezimizde hipoplastik sol kalp sendromu tanısıyla Norwood I işlemi uygulanan toplam 139 hasta (95 erkek, 44 kadın) retrospektif olarak incelendi.

Bulgular: Medyan doğum ağırlığı 3200 (dağılım, 3000-3350) g ve ameliyat sırasında medyan yaş yedi (dağılım, 5-10) gün idi. Hastaların büyük kısmında (%72) pulmoner akım, Sano şant ile sağlandı. İlk aşama sonrası sağkalım %41 idi. Kanama nedeniyle tekrar ameliyat (p=0.017), rezidü anatomik lezyon nedeniyle tekrar ameliyat (p=0.011) ve ameliyat sonrası birinci gün pik laktat seviyesi (p=0.029) hastane mortalitesi ile ilişkili idi. Taburcu edilen 57 hastanın 19'u (%33) ikinci aşamaya ulaşmadan kaybedildi. Otuz üç (%58) hastaya ikinci aşama ameliyatı uygulandı ve ikinci aşama sonrası sağkalım %94 idi. On üç hastaya üçüncü aşama ameliyatı uygulandı ve üçüncü aşama sonrası sağkalım %85 idi. Altı ay ve birinci, ikinci, üçüncü ve dördüncü yılda tahmini sağkalım olasılığı sırasıyla %33, %33, %25, %25 ve %22 idi.

Sonuç: Hastane ve aşamalar arası mortalite oranları halen yüksek olup, hipoplastik sol kalp sendromu tanılı hastaların sağkalma çabalarındaki en zorlayıcı zaman dilimi olarak görünmektedir. Anatomik rezidü defektlerin erken tanınması ve erken yeniden girişim yapılması, aşamalar arası dönemde yakın takip ve multidisipliner birikim ve tecrübe sonuçların kabul edilebilir seviyelere ulaşmasına yardımcı olabilir.

Anahtar sözcükler: Hipoplastik sol kalp sendromu, aşamalar arası mortalite, Norwood işlemi.

Received: June 20, 2021 Accepted: November 27, 2021 Published online: January 28, 2022

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Cite this article as:

Özdemir F, Korun O, Dedemoğlu M, Çiçek M, Biçer M, Yurdakök O, et al. Outcomes of Norwood procedure with hypoplastic left heart syndrome: Our 12-year single-center experience. Turk Gogus Kalp Dama 2022;30(1):26-35

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Hypoplastic left heart syndrome (HLHS) is one of the most complex and costly group of all congenital heart anomalies.^[1] Norwood I procedure described by William I. Norwood^[2] in 1980s is the first step of staged surgical approach for this complex anomaly and is still one of the riskiest operations of congenital heart surgery. The outcomes have recently improved with the application of different modifications and hybrid procedures and the development of surgical techniques and postoperative management.^[3-5] However, outcomes of this procedure from large cohorts are still missing in Turkey.

In the present study, we aimed to analyze the outcomes of one of the largest series of our country and to identify the risk factors of mortality.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at Dr. Siyami Ersek Thoracic and Cardiovascular Surgery Training and Research Hospital, Department of Pediatric Cardiovascular Surgery between January 2009 and December 2020. A total of 139 patients (95 males, 44 females; median age: 7 (IQR: 5-10) days; range, 1 to 39 days) who underwent Norwood I procedure with the diagnosis of HLHS were included. Those having a diagnosis other than HLHS were excluded. A very small subset (n=6) of HLHS patients who underwent a hybrid procedure were also excluded. A written informed consent was obtained from the parents of each patient. The study protocol was approved by the Dr. Siyami Ersek Thoracic and Cardiovascular Surgery Training and Research Hospital Ethics Committee (Date: 27.07.2018/No: 28001928-508.01-E). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Preoperative management and surgical technique

All patients received prostaglandin E1 (alprostadil 20 µg/mL) infusion between 0.005 and 0.1 µg/kg/min doses preoperatively.^[6] Oxygen saturation values of all patients were monitored closely up to the operation. The patients who were hemodynamically unstable and received mechanical ventilation and inotropic support. All surgical procedures were performed under general anesthesia. After standard median sternotomy, autologous pericardium was harvested. Both caval veins and the innominate artery were cannulated. Innominate artery was cannulated directly in patients undergoing right ventricle-to-pulmonary artery (RV-PA) shunt, whereas arterial cannulation was performed with the help of a polytetrafluoroethylene (PTFE) graft anastomosed to the innominate artery

in patients undergoing Blalock-Taussig (BT) shunt. In the last couple of years in the series, distal perfusion was achieved by performing descending aortic cannulation in most of the patients. In patients who underwent arch reconstruction under antegrade cerebral perfusion (ACP), systemic hypothermia at 28°C was used. In a small number of patients who underwent total circulatory arrest (TCA) during aortic arch reconstruction, 24°C systemic hypothermia was preferred. In patients who underwent whole-body perfusion with descending aortic cannulation during the arch reconstruction, 32°C hypothermia was preferred. Aortic arch reconstruction was performed by using glutaraldehyde-fixed autologous pericardium. Pulmonary flow was instituted through a modified BT (mBT) shunt or an RV-PA shunt. As a rule of thumb, RV-PA shunt was preferred in patients with aortic atresia and/or ascending aortic diameter less than 2 mm. In addition, the decision was made according to the surgeon's preference and patient's anatomy. Atrial septectomy was performed in all patients. After completion of the surgery, sternum was left open and skin tissue was closed primarily or by sterile patch material in patients having myocardial edema.

Follow-up and outcome events

Primary outcomes of interest were in-hospital mortality and inter-stage mortality rates during the follow-up. The other outcomes of interest were long-term survival. Demographics and echocardiographic findings were reviewed. The need for mechanical ventilation and the initial blood lactate level in the operation room were noted. Intraoperative perfusion data and blood lactate levels, cerebral, myocardial, end organ protection techniques, and type of shunt were noted. Postoperative blood lactate levels were reviewed and the peak value was noted on the first day of postoperative follow-up. Complications such as acute renal failure requiring dialysis, permanent neurological deficit, atrioventricular (AV) block requiring pacemaker implantation, requirement of mechanical circulatory support, re-exploration for bleeding, requirement of reintervention and length of stay in the intensive care unit (ICU) and hospital were also noted. In addition to hospital registry data, the National Personal Health Record System was used to confirm long-term survival.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 21.0 software (IBM Corp., Armonk, NY, USA). The normality distribution of variables

Table 1. Baseline patient characteristics and echocardiographic findings

Variables	All patients			Survivors			Non-survivors			p			
	n	%	Median	IQR	n	%	Median	IQR	n		%	Median	IQR
Age (day)			7	5-10			7	5-11			7	4-10	0.998
Sex													
Male	95	68			35	61			60	73			0.142
Birth weight (g)			3,200	3,000-3,350			3,250	3,100-3,400			3,200	3,000-3,320	0.217
Need for mechanical ventilation	28	23			7	14			21	30			0.041*
Additional cardiac anomaly													
TAPVR	4	3			1	2			3	4			0.509
PAPVR	4	3			1	2			3	4			0.509
PLSVC	5	4			2	4			3	4			0.667
Cor triatriatum	2	1			1	2			1	1			0.654
Dextrocardia	1	1			0	0			1	1			0.59
Atrial isomerism	1	1			0	0			1	1			0.59
Levoatrial cardinal vein	1	1			0	0			1	1			0.59
Diameters													
Ascending aorta (≤ 2.5 mm)	49	35			17	30			32	39			0.264
Ascending aorta (> 2.5 mm)	90	65			40	70			50	61			
Ascending aorta (mm)			3.3	2.2-5			3.8	2.5-5			3.1	2.1-4.9	0.288
Proximal arch (mm)			4	3.5-4.5			4	3.7-5			3.9	3.4-4	0.141
Distal arch (mm)			4	3.3-4.4			4	3.5-4.5			3.6	3-4	0.054
Isthmus (mm)			3	2.5-3.5			3.3	2.8-3.5			3	2.5-3.6	0.517
Aortic atresia	66	47			24	42			42	51			0.29
Aortic stenosis	73	53			33	58			40	49			
Tricuspid valvular insufficiency													
None or trace	53	38			20	35			33	40			0.424
Mild	49	35			23	40			26	32			
\geq Moderate	37	27			14	25			23	28			

IQR: Interquartile range; TAPVR: Total anomalous of pulmonary venous return; PAPVR: Partially anomalous of pulmonary venous return; PLSVC: Persistent left superior vena cava.

Table 2. Operative and postoperative data

Variables	All patients			Survivors			Non-survivors			p			
	n	%	Median	IQR	n	%	Median	IQR	n		%	Median	IQR
Duration of operation (min)			345	270-396			324	270-372			360	265-420	0.201
Cross clamp time (min)			75	54-105			70	53-102			79	54-107	0.599
CPB time (min)			163	136-205			150	127-197			176	146-215	0.053
Perfusion strategy													
Beating heart surgery	5	4			1	2			4	5			0.316
TCA	9	7			3	5			6	7			0.352
TCA time (min)			45	25-56			58	38-63			42	12-47	0.177
ACP	111	78											
ACP time (min)			66	49-85			59	45-76			70	50-88	0.17
ACP + Descending aortic perfusion	19	14			9	16			10	12			0.544
Type of shunt													
mBT shunt	39	28			14	25			25	30			0.544
Sano shunt	100	72			43	75			57	70			
Blood lactate (mmol/L)													
Initial lactate at anesthesia induction			2	1.4-2.9			1.8	1.3-2.2			2.1	1.5-4.1	0.003*
Intraoperative peak lactate level			9.3	6.9-11.6			8	6.4-9.5			10.2	8.2-13	<0.001*
Intraoperative final lactate			9.2	6.7-12.2			6.8	5.5-9			10.7	8.4-13	<0.001*
First postoperative day peak lactate level			11	7.9-14.6			8.1	6.1-11.3			13.9	10.4-16	<0.001*
Complications													
Peritoneal dialysis	54	39			17	30			37	45			0.069
Reoperation for bleeding	14	9			2	4			11	13			0.049*
Reintervention for residual defect or shunt	16	12			1	2			15	18			0.003*
Diaphragmatic plication	6	4			6	11			0	0			0.004*
Tracheostomy	13	9			10	18			3	4			0.006*
Neurologic deficit persisting at discharge	-	-			-	-			-	-			
Deep sternal wound infection	4	3			1	2			3	4			0.509
ECMO support	27	19			2	4			25	31			<0.001*

IQR: Interquartile range; CPB: Cardiopulmonary bypass; TCA: Total circulatory arrest; ACP: Antegrade cerebral perfusion; mBT: Modified Blalock-Taussig; ECMO: Extra-corporeal membrane oxygenation.

was evaluated using the Kolmogorov-Smirnov/ Shapiro-Wilk tests. Data were expressed in mean \pm standard deviation (SD) or median (min-max) for continuous variables and in number and frequency for categorical variables. Independent sample t-test was or Mann-Whitney U test were used to compare continuous variables and the Pearson chi-square or Fisher exact tests for categorical variables. Univariate and multivariate analyses using binary logistic regression were performed to determine independent predictors for dependent parameter. To obtain a cut-off value and area under the curve (AUC) for related parameters, the receiver operating characteristic (ROC) curve analysis was performed. Survival curves and rates were obtained from the Kaplan-Meier analysis. A *p* value of <0.05 was considered statistically significant.

RESULTS

The median birth weight was 3,200 (range, 3,000 to 3,350) g and the median age at the time of operation was seven (range, 5 to 10) days. In addition to diagnosis of HLHS, total anomalous of pulmonary venous return (TAPVR) in four patients, partially anomalous of pulmonary venous return (PAPVR) in four patients, persistent left superior vena cava (PLSVC) in five patients, cor triatriatum in two patients, dextrocardia in one patient, atrial isomerism in one patient, and isolated levoatrial cardinal vein in one patient were observed. The ascending aorta diameter was less than 2.5 mm in 49 (35%) patients. Sixty-six (47%) patients had aortic valvular atresia with ductus dependent coronary circulation. In 37 (27%) patients, there was moderate or severe tricuspid valve insufficiency. Baseline patient characteristics and echocardiographic findings are summarized in Table 1.

In addition to the Norwood I procedure, TAPVR repair was performed in four patients and cor

triatriatum repair was performed in one patient concomitantly. Aortic arch reconstruction was performed under TCA in nine (7%) patients and the median duration of TCA was 45 (range, 25 to 56) min. In 130 (94%) patients, arch reconstruction was performed under ACP and the median duration of ACP was 66 (range, 49 to 85) min. In 19 of these patients, in addition to ACP, lower body was perfused by descending aortic cannulation. In the subgroup analysis between the groups with and without descending aortic perfusion, intraoperative maximal blood lactate level was found to be significantly lower in the descending aorta perfusion group ($p=0.023$). The median cross-clamp and bypass time were 75 (range, 54 to 105) min and 163 (range, 136 to 205) min, respectively. The RV-PA (Sano) shunt was preferred to provide pulmonary flow in the majority (72%) of the patients. Sternal closure was delayed in all of patients routinely. All operative data are listed in Table 2.

According to the univariate logistic regression analysis for in-hospital mortality after first stage, requirement of mechanical ventilation preoperatively, blood lactate levels, reoperation for bleeding, reintervention for residual defect or shunt and need to ECMO support were statistically significant higher in the non-survivors group. There were no significant differences between the groups in terms of the aortic diameters, additional cardiac anomalies, tricuspid valvular insufficiency, descending aortic perfusion and type of shunt.

The postoperative peak blood lactate level was found to be an independent predictor of in-hospital mortality. Thirteen (9.4%) patients required reoperation for bleeding in the early postoperative period. Early postoperative reintervention was needed in 16 (11.5%) patients. These two parameters were

Table 3. Multivariate analysis of factors predicting mortality

Variables	OR	<i>p</i>
Initial lactate at anesthesia induction	1.474	0.073
Intraoperative peak lactate level	1.169	0.267
Intraoperative final lactate	1.095	0.618
First postoperative day peak lactate level	1.282	0.029*
Preoperative need of mechanical ventilation	3.023	0.100
Reoperation for bleeding	17.965	0.017*
Reintervention for residual defect or shunt	21.598	0.011*

OR: Odds ratio.

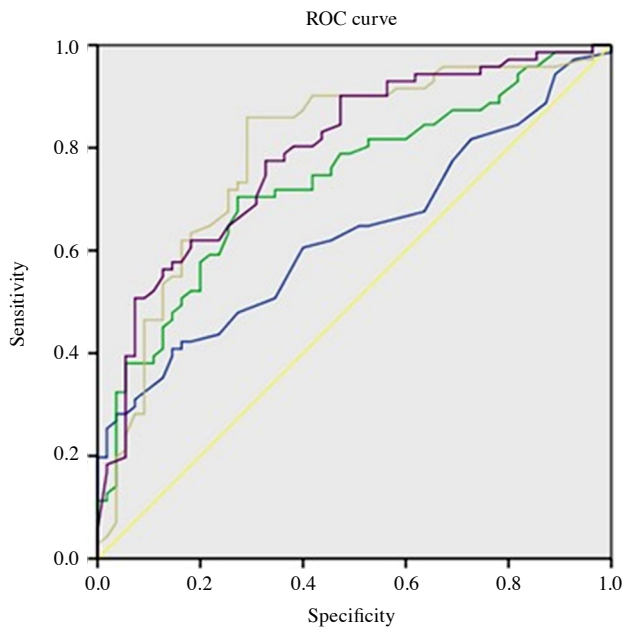


Figure 1. ROC curves of lactate levels for mortality.
Blue Curve: Initial lactate at anesthesia induction, Green curve: Intraoperative peak lactate level, Beige curve: Intraoperative final lactate, Purple curve: 1st postoperative day peak lactate level.

also found to be independent predictors of in-hospital mortality (Table 3).

The reasons for reinterventions were shunt stenosis in 10 patients, pulmonary over-flow in two patients, restrictive interatrial communication in one patient, pulmonary branch stenosis in two patients, and residual coarctation in one patient.

Fifty-four (39%) patients required peritoneal dialysis treatment due to excessive edema and/or acute kidney injury. Twenty-seven (19%) of the patients required extracorporeal membrane oxygenation (ECMO) support. Indications for ECMO support were low cardiac output (LCO) in 18 patients, hypoxia due to shunt dysfunction in six patients, and extracorporeal cardiopulmonary resuscitation (ECPR) in three patients. Only two of them (7%) could be weaned

from ECMO and survived. Diaphragmatic plication procedure was done in six (4%) patients who had phrenic nerve paralysis. Tracheostomy was performed in 13 (9%) patients, due to the inability to wean from mechanical ventilation. Apart from a patient with congenital hydrocephalus, permanent neurological deficits were not observed in any patient. The median duration of ICU and hospital stay after operation were 14 (range, 1 to 25) and 16 (range, 1 to 29) days for all patients, respectively and 25 (range, 15 to 41) and 29 (range, 22 to 46) days for survivors, respectively. In-hospital mortality was observed in 82 (59%) of all patients.

In the ROC curve analysis, intraoperative final lactate level (sampled at the end of the operation) had the largest AUC (0.794, Figure 1) to estimate the hospital mortality. The cut-off value was 7.75 mmol/L with a sensitivity of 86% and a specificity of 71%. Of note, in our series, an initial lactate level (at anesthesia induction) higher than 4.5 mmol/L indicated mortality with a specificity of 100%, despite sensitivity of 20% (Table 4, Figure 1).

The follow-up was complete for 99% of the patients. One patient was lost to follow-up after 13 months in the first inter-stage period. In this period, three patients required reintervention. Balloon aortoplasty was performed in two patients due to re-coarctation of aorta and one patient required balloon angioplasty for stenosis of mBT shunt and left pulmonary artery (LPA). Nineteen (33%) of 57 patients died during the first inter-stage period who were discharged after Norwood I. Four patients were still waiting for the second stage.

The second stage operation were performed in 33 patients. In addition to the bidirectional cavopulmonary connection procedure, arch reconstruction was performed in four patients due to re-coarctation of aorta and tricuspid valve repair was performed in one patient due to severe valvular insufficiency concomitantly. The median age of the patients was nine (range, 7 to 12) months. Thirty-one

Table 4. ROC analysis of lactate levels for mortality

Variables	Area	SE*	p	%95 CI
Initial lactate at anesthesia induction	0.631	0.49	0.012	0.535-0.727
Intraoperative peak lactate level	0.734	0.44	0.000	0.647-0.821
Intraoperative final lactate	0.794	0.42	0.000	0.712-0.876
First postoperative day peak lactate level	0.790	0.40	0.000	0.711-0.869

ROC: Receiver operating characteristic; CI: Confidence interval; * Under the non-parametric assumption.

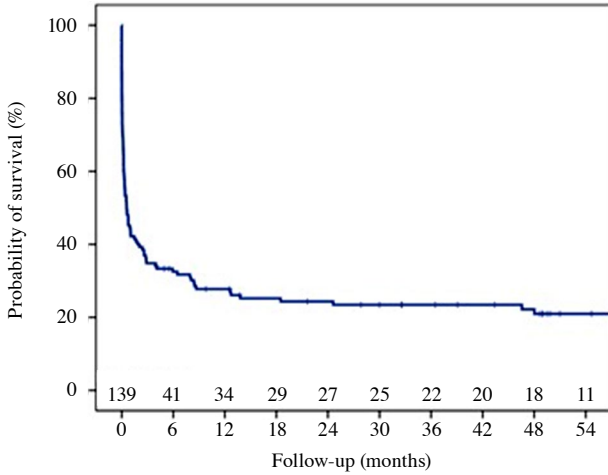


Figure 2. Survival curve of all patients.

Six months, 1 year, 2 years, 3 years and 4 years probability of survival rates were 33%, 33%, 25%, 25%, and 22%, respectively.

of them were discharged and in-hospital mortality was observed in two (6%) patients.

In the second, inter-stage period, four patients underwent LPA stenting due to proximal LPA stenosis.

Three (10%) of thirty-one patients died during the second inter-stage period. Fifteen patients were still waiting for the third stage.

The third stage operation were performed in 13 patients. The median age of the patients at stage III was 47 (range, 47 to 50) months. In the early postoperative period, left and right pulmonary artery (RPA) stenting was performed to relieve LPA and RPA stenosis in one patient. Eleven of them were discharged, and hospital mortality was observed in two patients. Balloon aortoplasty and RPA stenting were performed in one patient in the post-stage III period. The estimated probability of survival at six months, and one, two, three, and four years were 33%, 33%, 25%, 25%, and 22% respectively (Figure 2).

DISCUSSION

In our series, the highest mortality rate in HLHS patients was detected in the early postoperative period after Norwood I procedure. In the multivariate analysis, reoperation due to bleeding and early unplanned reintervention were found to be the main predictors of mortality. Also, the first postoperative day peak

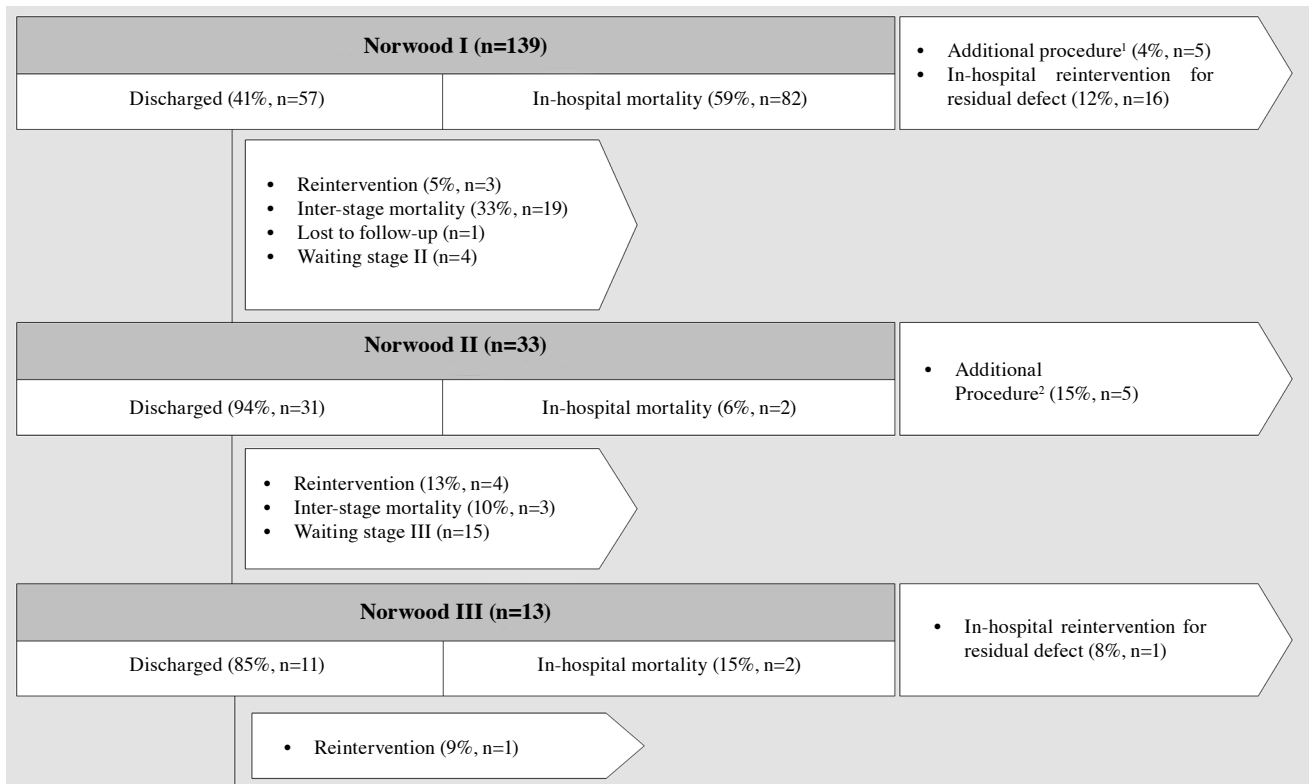


Figure 3. Summary of the patient outcomes.

1- In addition to the “Norwood I” procedure, TAPVR repair was performed in four patients and cor triatriatum repair was performed in one patient concomitantly. 2- In addition to the “Bidirectional Cavopulmonary Connection” procedure, arch reconstruction was performed in four patients and tricuspid valve repair was performed in one patient concomitantly. TAPVR: Total anomalous of pulmonary venous return.

lactate level was found to be an independent predictor of mortality. In the ROC analysis, higher levels than 7.75 mmol/L for intraoperative final lactate levels were found to be cut-off values associated with mortality. Although the sensitivity was low, there were no early survivors among the patients with an initial lactate level higher than 4.50 mmol/L. In the subgroup analysis, intraoperative peak lactate level was found to be significantly lower in the descending aortic cannulation group; however, it was not associated with mortality. The inter-stage period stands out as another period with high mortality rates.

Unfortunately, as seen in the Kaplan-Meier curve (Figure 2), only one in five (22%) patients could reach the age of five, predominantly due to the in-hospital and first inter-stage mortality. High mortality and morbidity rates similar to our series have also been reported in the literature.^[7] The single digit mortality rates reported from experienced centers were achieved by learning from their mistakes by surgical modifications, new strategies and improved multidisciplinary perioperative care.^[8] As we understand from our early experience and the reports from other institutes, the mortality and morbidity rates of clinics can be quite high, when they are in the learning curve for Norwood surgery^[9,10] and it can be speculated that Norwood surgery is still in the development phase in our country.^[11-13] However, early mortality after Norwood surgery still stands out as the most important problem that needs to be tackled.

Considering the promising results from expert centers, we questioned if the hybrid procedure could be an option to improve survival. There are clinics in the world that have adopted hybrid procedure as the primary palliation method and have achieved favorable results. According to the Giessen team, interventional procedures should only be optimized by using innovative self-expandable stents and close follow-up is very important in the inter-stage period.^[14] However short- and long-term outcomes of hybrid procedures have shown great variability including some very unfavorable results.^[15] In Turkey, Erek *et al.*^[11] reported the comparison of surgical and hybrid Norwood procedures and showed that the hybrid approach did not have promising results. Discouraging results were obtained in our attempts as well, five of six patients died in the early period and one died in the inter-stage period. The difficulty in obtaining special interventional materials and following-up closely in the inter-stage period (due to the fact that majority of the patients living in rural areas) are seen as the most important obstacles to the success of the hybrid method for our patient population.

In our series, reoperation due to bleeding and unplanned reintervention were found to be the main predictors of mortality. This finding can imply that the high mortality is mostly related to surgical complications. However, the results of a recent article published by Boston Children's Hospital group^[16] contradict this situation. In this article, the authors analyzed the results of 500 Norwood surgeries performed over 20 years by classifying them according to their technical performance score (TPS). Considering the results of the study, even in the group with the worst TPS, that is, the group with many residual defects, the mortality rate was 32%, which is lower than our series. Remarkably, in the results of the Boston group,^[16] the subgroup of patients with the worst TPS score had an 89% rate of unplanned reintervention, which was significantly higher than in our series. This indicates that the residual lesions are not uncommon even in the most experienced centers. Effective detection and timely correction of them may be a primary goal to improve Norwood I outcomes.

High lactate levels have been reported in the literature as a predictor of poor prognosis. In our series, the postoperative first day peak serum lactate level was found to be an independent predictor of mortality. Murtuza *et al.*^[17] reported that the inability to clear blood lactate to less than 6.76 mmol/L within 24 h after Norwood I surgery was highly predictive of early mortality. Also in our series, in the ROC analysis performed to find out which lactate level was associated with mortality, the highest AUC value was found to be intraoperative final lactate level and the cut-off value was 7.75 mmol/L. In another study, the postoperative peak lactate level within the first 48 h was found to be a risk factor for the need of ECMO support.^[18] In the light of these findings, it can be concluded that lactate level is an important predictor of prognosis; however, it is worth investigating whether definitive clinical algorithms can be established using these cut-off values. Our current practice in our clinic is the use of ECMO in the presence of hemodynamic instability with high lactate levels as a result of low cardiac output syndrome. On the other hand, considering that mortality is very high in patients under ECMO, it would be more rational to create a better preoperative and intraoperative strategy not to increase lactate levels that would require ECMO support. In the light of this view, all-region perfusion strategies including coronary and distal perfusion have been experienced in different clinics.^[19,20] To achieve better tissue perfusion and lower lactate levels, in most of the patients who were recently operated in our clinic, distal perfusion was provided by cannulation of the descending aorta during

the arch reconstruction phase. There was no significant difference in the early mortality and morbidity rates between the descending aortic cannulation subgroup and the others. However, when the lactate levels were examined, the intraoperative peak lactate level was significantly lower in the descending aortic cannulation subgroup. This technique continues to be used in our clinic, considering its potential benefits.

The first inter-stage period is a very risky time period in terms of acute hemodynamic decompensation. In this period, close follow-up of the patients is of utmost importance. According to the literature, inter-stage mortality rate ranges from 2 to 20%.^[21] This rate was found to be higher than the literature in our series. The possible reason is that most of our patients have inhabited at the rural area having lack of fully equipped pediatric heart center. In the light of literature data, the mortality more often occurs within the first 24 h after the first symptom in the inter-stage period.^[22] Even though, the admission of patient to the hospital may be delayed within 24 h, even if the patient resides in the city center. In some experienced centers, home surveillance system and in-hospital inter-stage follow-up algorithms have developed to solve this problem.^[23,24] In our clinic, a similar organization has been implemented recently. The parents were recommended to obtain a portable pulse oximeter and a baby scale to record the oxygen saturation and the weight of the patient daily. They also recorded the amount of feeding and urine output. In general, patients are given certain criteria and are advised to call the hospital if any of these criteria are breached. Our aim with the home surveillance system is to reduce the inter-stage mortality. The outcomes of this approach in our cohort have not been analyzed, yet.

The main limitation of this study is its single-center, retrospective design. In addition, only basic data were available about preoperative condition and data such as inotrope score, cardiac output, and sepsis were unable to be reached. Furthermore, changes in surgical technique, depending on the learning period of our center or the surgeon's preference may have affected the outcomes.

In conclusion, we particularly consider that our study with the large patient population reflects the situation of outcomes of Norwood procedure in our country. Although some improvement has been achieved in time, the most important problems are still high early postoperative and inter-stage mortality after stage I in our setting. Perfusion strategies focusing on providing better tissue perfusion and keeping lactate levels lower and more aggressive postoperative follow-up for early

recognition and early reintervention of anatomical residual defects may help to improve the outcomes. We believe that our newly launched home surveillance system would decrease the inter-stage mortality rates.

Declaration of conflicting interests

The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding

The authors received no financial support for the research and/or authorship of this article.

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