Factors affecting Fontan length of stay: Results from the Single Ventricle Reconstruction trial

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ABSTRACT

Background: In the Single Ventricle Reconstruction trial, infants with hypoplastic left heart syndrome (HLHS) who received a right-ventricle-to-pulmonary-artery shunt (RVPAS) versus a modified Blalock-Taussig shunt (MBTS) had lower early postoperative mortality, but more complications at 14 months. We explored the effect of shunt type and other patient, medical, and surgical factors on postoperative length of stay (LOS) after the Fontan operation.

Methods: Fontan postoperative course was ascertained from medical record review. Cox proportional hazards modeling was used to identify factors associated with LOS.

Results: Of 327 subjects who underwent Fontan, 323 were analyzed (1 death, 1 biventricular repair, 2 with missing data). Median age and weight at Fontan were 2.8 years (interquartile range [IQR]: 2.3, 3.4) and 12.7 kg (IQR: 11.4, 14.1), respectively. Fontan type was extracardiac in 55% and lateral tunnel in 45%; 87% were fenestrated. The RVPAS and MBTS subjects had similar LOS (median 11 days [IQR: 9, 18] vs 10 days [IQR: 9, 13]; $P = .23$). Independent risk factors for longer LOS were treatment center ($P < .01$), LOS at stage II (hazard ratio [HR] 1.02 for each additional day; $P < .01$), and pre-Fontan complications (HR 1.03 for each additional complication; $P = .04$). Use of deep hypothermic circulatory arrest at Fontan (HR 0.64; $P = .02$) was independently associated with shorter LOS. When center was excluded from the model, pre-Fontan complications and use of circulatory arrest were no longer significant; instead, older age at stage II (HR 1.08 for each additional month; $P = .01$) predicted longer LOS. In 254 subjects who had a pre-Fontan echocardiogram, at least moderate tricuspid regurgitation was independently associated with longer LOS,

Kaplan-Meier curves comparing the time to hospital discharge after a Fontan operation for the 2 shunt groups (blue = modified Blalock-Taussig shunt; red = right-ventricle-to-pulmonary-artery shunt) in transplant-free survivors (logrank $P = .24$).

Central Message

Longer length of stay after a Fontan procedure was associated with greater overall earlier medical complexity, and not with the shunt type used in a Norwood operation.

Perspective

In this follow-up analysis of the multicenter, prospective Single Ventricle Reconstruction trial cohort, survival after a Fontan operation was 99.7%. Length of stay after the Fontan procedure was not associated with shunt type. Rather, global measures of earlier medical morbidity predicted longer LOS. Future studies are needed to assess the impact of early postoperative morbidity on late Fontan outcomes.

See Editorial Commentary page 676.

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Abbreviations and Acronyms

DHCA	= deep hypothermic circulatory arrest
HLHS	= hypoplastic left heart syndrome
HR	= hazard ratio
IQR	= interquartile range
LOS	= length of stay
MBTS	= modified Blalock-Taussig shunt
RVPAS	= right-ventricle-to-pulmonary-artery shunt
SVR	= Single Ventricle Reconstruction trial

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both with center (HR 1.72; $P < .01$) and without center in the model (HR 1.49; $P = .02$).

Conclusions: In this multicenter prospective cohort of subjects with HLHS, Norwood shunt type was not associated with Fontan LOS. Rather, global measures of earlier medical complexity indicate greater likelihood of longer LOS after the Fontan operation. (J Thorac Cardiovasc Surg 2016;151:669-75)

Since its original description, the Fontan operation has been performed for various single-ventricle anomalies.¹ The Fontan circuit relies on systemic venous pressure to propel blood through the lungs; it therefore depends on low pulmonary vascular resistance, which in turn is affected by such factors as ventricular function and pulmonary artery distortion. Few studies have explored the role of shunt type during the Norwood procedure for hypoplastic left heart syndrome (HLHS) in modulating these factors and affecting the Fontan postoperative course.²

The Single Ventricle Reconstruction (SVR) trial showed better transplant-free survival at 12 months in patients assigned to the right-ventricle-to-pulmonary-artery shunt (RVPAS), compared with the modified Blalock-Taussig shunt (MBTS), at the time of the Norwood operation for HLHS and other, related, single right-ventricular anomalies.³ However, subjects in the RVPAS group had more pulmonary artery stenosis, smaller pulmonary arteries, greater need for intervention, and more complications. These results raise concern, given that pulmonary artery stenosis has been associated with poor outcomes after the Fontan operation.⁴ In addition, the incision in the right ventricle that is required

for placement of the RVPAS can lead to scar formation, which has the potential to diminish ventricular function and be a nidus for arrhythmia.⁵⁻⁷ In the SVR trial cohort, by the time of pre-Fontan echocardiography, survivors who had been randomized to the RVPAS, compared with the group who received the MBTS shunt, showed greater deterioration in right-ventricular ejection fraction.^{8,9}

All transplant-free survivors of the SVR trial were eligible for enrollment in the SVR Extension study (SVR II), which compares clinical outcomes and right-ventricular performance through 6 years postrandomization. Annual medical histories were obtained when patients were between 2 and 6 years old, and data were collected during the Fontan procedure hospitalization. This well characterized cohort provides a unique opportunity to describe outcomes after the Fontan operation for HLHS, and related, single right-ventricular anomalies, and to determine factors that affect these outcomes from birth to the time of the Fontan procedure.

We hypothesized that subjects who received an RVPAS would have a longer postoperative length of stay (LOS) after undergoing the Fontan procedure, compared with those who received an MBTS. Postoperative LOS was specifically selected as the primary outcome for this analysis, owing to the anticipated low incidence of death, transplantation, or Fontan takedown in this cohort. In addition, we sought to determine the association of patient characteristics with medical and surgical factors relating to LOS after the Fontan operation.

METHODS

Study Design and Data Collection

In the Pediatric Heart Network's SVR trial,³ infants with HLHS and related, single right-ventricular anomalies, from 15 centers across North America, were randomized to receive the RVPAS or MBTS during the Norwood operation. Patients who had undergone the Fontan operation as of April 1, 2013 were eligible for inclusion in this analysis. The study was approved by the institutional review board or research ethics board at each participating center, and written informed consent was obtained from parents and/or guardians before enrollment in the trial.

The shunt that was in place at the end of the Norwood operation was used for the current analysis (as opposed to intention to treat). An annual medical history was obtained from transplant-free survivors, via phone interview with parents and/or guardians and review of medical records. Medical factors that were analyzed include the following: LOS, at both Norwood and stage II; the number of serious adverse events in the first 12 months, and the number of complications and interventional catheterizations in the time period from before the Norwood to the Fontan procedure.

Nonfatal serious adverse events that were recorded from the time of randomization in the SVR trial to age 12 months included acute shunt failure, cardiac arrest, use of extracorporeal membrane oxygenation support, unplanned cardiovascular reoperation, and necrotizing enterocolitis. Other potential risk factors, including patient characteristics, are listed in [Appendix E1](#). Only those pre-Fontan echocardiograms that were performed at the study center were reviewed in a core laboratory, and pre-Fontan cardiac catheterization was performed per standard clinical practices at each center. The month in which the Fontan operation was performed was included as a potential seasonal predictor of LOS, with 2 categories: November through March (the peak time of year for viral

respiratory illnesses to occur); and April through October. The course of patients' health after the Fontan operation was ascertained by review of medical records.

Statistical Analysis

Hospital LOS was defined as the number of days from the date of the Fontan operation (day 1) to the discharge date. Descriptive statistics are presented as mean $\pm$ SD, medians with interquartile range (IQR), and percentages, as appropriate. A univariate Cox proportional hazard regression model was used to identify associations of clinical factors with time to hospital discharge after the Fontan operation. The proportional hazard assumption was verified. Associations that were significant at $P \leq .20$ were considered for inclusion in the multivariable model.

Owing to the large amount of missing data, variables that were related to genetic assessment, pre-Fontan echocardiogram results and use of pre-Fontan cardiac catheterization were initially excluded from modeling. A stepwise selection method was used, with multivariable Cox regression, to build 2 models that included or excluded, as a variable, the center where patients were treated. Based on these 2 models (ie, with vs without treatment center), the variables related to genetic assessment, pre-Fontan echocardiogram results, and use of pre-Fontan catheterization were added (each group separately), to determine their impact. All analyses were conducted using SAS, version 9.3 (SAS Institute, Inc, Cary, NC).

RESULTS

Among 549 SVR trial subjects who were randomized to the RVPAS or MBTS shunt for the Norwood operation, stage II was performed for 400 (73%); 380 (95%) of these patients had transplant-free survival to discharge. As of April 1, 2013, of these 380 patients, 21 had died, 10 had received transplants, 1 was listed for transplant, Fontan was planned in 11 and not planned in 6, 3 were alive with unknown status, and 1 was lost to follow-up.

The Fontan operation was performed in 327 transplant-free survivors, from January 2007 to April 2013, of whom 323 constitute our analytic cohort. Of the remaining 4, 1 died, 2 had no available perioperative data, and 1 underwent biventricular repair during the Fontan hospitalization. The most common anatomic defect was HLHS, which was present in 285 patients (88%). Five subjects had obstructed pulmonary venous return, and 2 had heterotaxy. The types of stage II procedures performed were as follows: bidirectional Glenn in 192 (59%); hemi-Fontan in 84 (26%); bilateral bidirectional Glenn in 34 (11%); and other in 13 (4%).

Nearly half of the subjects ($n = 154$) had undergone ≥ 1 interventional catheterization before the Fontan operation. Interventions included balloon and/or stent angioplasty for coarctation in 66 (20%), pulmonary artery balloon and/or stent angioplasty in 24 (7%), and coil embolization of aortopulmonary collateral vessels in 56 (17%). In the 254 patients who had a pre-Fontan echocardiogram that was evaluable for degree of tricuspid regurgitation, at least moderate tricuspid regurgitation was present in 45 (18%). Cardiac catheterization in anticipation of the Fontan procedure was performed in 260 (80%) patients. The mean systemic ventricular end-diastolic pressure

and the transpulmonary gradient were 8.3 ± 2.8 and 3.4 ± 2.9 mm Hg, respectively. Pulmonary artery abnormalities were documented on angiography in 76 of 260 (29%) patients.

Baseline characteristics by shunt type, for those who underwent the Fontan procedure, indicate that the MBTS group had both a lower weight-for-age z-score (-0.9 ± 1.1 vs -0.6 ± 1.2 ; $P = .03$) and a lower height-for-age z-score (-1.4 ± 1.4 vs -1.0 ± 1.5 ; $P = .01$) at 14 months, compared with those in the RVPAS group (Table 1). Serious adverse events in the first 12 months occurred more frequently in the MBTS group ($P = .03$). However, those who received the MBTS had fewer cardiac catheterizations during the time period from birth to the Fontan procedure (n [IQR]): (0 [0, 1] vs 1 [0, 2]; $P = .001$). No other differences were found between the 2 groups.

Fontan Procedure Characteristics

Median age and weight at the time of the Fontan procedure were 2.8 years (IQR: 2.3, 3.4) and 12.7 kg (IQR: 11.4, 14.1), respectively. The median weight-for-age z-score and height-for-age z-score were -0.5 (IQR: -1.3 to 0.1) and -1.1 (-1.8 to -0.3), respectively. The Fontan procedure type was extracardiac in 178 (55%), and lateral tunnel in 145 (45%) patients; 280 (87%) underwent fenestration. Subjects undergoing the extracardiac procedure were older than those who underwent the lateral tunnel procedure (3.2 ± 0.8 vs 2.5 ± 0.7 years; $P < .001$). Deep hypothermic circulatory arrest (DHCA) was used for 93 (29%) subjects. Concurrent procedures were performed at the time of the Fontan in 104 (32%) subjects, with the 2 most common additional procedures being pulmonary arterioplasty for pulmonary artery stenosis (45 [14%]), and atrioventricular valvuloplasty or repair in 29 (9%) (Table 2).

Postoperative Outcomes

One patient died, and none required either Fontan take-down or transplantation before discharge. The median LOS for survivors was 10 days, and it was similar for the 2 shunt types (11 days [IQR: 9, 18] for RVPAS vs 10 days [IQR: 9, 13] for MBTS; $P = .23$) (Figure 1). Pleural drainage that persisted for >7 days occurred in 58 (18%) patients. Other complications included arrhythmias in 50 (15%), infections in 37 (11%), and thromboembolic complications in 7 (2%). Thirty-one (10%) patients were readmitted within 30 days of discharge. None of these outcomes differed by shunt type.

Factors Associated with Length of Stay

Factors associated with longer LOS, by univariate analysis, are listed in Table 3. In the final multivariable model that included center (Table 4), independent risk factors for

TABLE 1. Baseline characteristics of subjects, by shunt type (n = 323)

Characteristic	n	MBTS	n	RVPAS	P value
Gestational age (wk)	150	38.4 ± 1.3	173	38.3 ± 1.4	.77
Gestational age <37 wk	150	10 (7)	173	14 (8)	.63
Birth weight (kg)	150	3.2 ± 0.5	173	3.1 ± 0.5	.38
Birth weight <2.5 kg	150	18 (12)	173	13 (8)	.17
Gender, male	150	96 (64)	173	111 (64)	.98
White race	149	128 (86)	172	141 (82)	.34
Hispanic race	147	21 (14)	172	35 (20)	.16
Socioeconomic score	143	0.2 ± 4.7	169	0.6 ± 5.6	.50
Below federal poverty level (%)	143	8.4 (3.2, 13.3)	169	8.3 (3.9, 17.2)	.19
Hypoplastic left heart syndrome	150	131 (87)	173	154 (89)	.64
Aortic atresia	150	90 (60)	173	111 (64)	.44
Genetic syndrome	150		173		.64
Yes		7 (5)		5 (3)	
Unknown		28 (19)		37 (21)	
No		115 (77)		131 (76)	
Nonsyndromic abnormality	150		173		.77
Yes		32 (21)		40 (23)	
Unknown		28 (19)		36 (21)	
No		90 (60)		97 (56)	
Center single-ventricle treatment volume	150	27.5 (18.9, 32.2)	173	27.5 (17.1, 32.2)	.20
Surgeon Norwood volume	150	12.6 (7.3, 14.8)	173	12.6 (7.3, 13.6)	.63
Age at stage II (mo)	150	5.5 ± 2.2	173	5.2 ± 1.6	.20
Length of stay at stage II (d)	150	8 (6, 11)	173	8 (6, 13)	.26
Weight for age z-score, 14 mo (WHO)	139	−0.9 ± 1.1	163	−0.6 ± 1.2	.03
Length for age z-score, 14 mo (WHO)	139	−1.4 ± 1.4	163	−1.0 ± 1.5	.01
Cardiac surgeries prior to Fontan	150	1.0 (0.0, 1.0)	173	1.0 (0.0, 1.0)	.47
Noncardiac surgeries prior to Fontan	150	0.0 (0.0, 1.0)	173	0.0 (0.0, 1.0)	.98
Complications prior to Fontan	150	5.0 (3.0, 8.0)	173	5.0 (3.0, 8.0)	.95
Serious adverse events (12 mo)	150	0.0 (0.0, 1.0)	173	0.0 (0.0, 0.0)	.03
Catheterization prior to Fontan	150	0.0 (0.0, 1.0)	173	1.0 (0.0, 2.0)	.001
≥Moderate tricuspid regurgitation on pre-Fontan echocardiogram	119	20 (17)	136	25 (18)	.87
Age at Fontan (y)	150	2.8 ± 0.8	173	2.9 ± 0.8	.21
Weight for age z-score at Fontan	116	−0.6 ± 1.0	142	−0.6 ± 1.0	.79
Length for age z-score at Fontan	116	−1.1 ± 1.3	141	−1.0 ± 1.3	.59

Values are n (%), mean ± SD, or median (interquartile range), unless otherwise indicated. Socioeconomic score was assigned using a US Census–based score derived from 6 measures related to income, housing, and occupationally related features of the subject's census block tract at the time of randomization. MBTS, Modified Blalock-Taussig shunt; RVPAS, right-ventricle-to-pulmonary-artery shunt; WHO, World Health Organization.

longer LOS were as follows: treatment center ($P < .01$); LOS at stage II (hazard ratio [HR] 1.02 for each additional day; $P < .01$); and pre-Fontan complications (HR 1.03 for each additional complication; $P = .04$). Use of DHCA at the time of the Fontan procedure (HR 0.64; $P = .02$) was independently associated with shorter LOS. When the treatment center variable was excluded from the multivariable model, pre-Fontan complications and use of DHCA were no longer significant, and older age at stage II (HR 1.08 for each additional month; $P = .01$) entered the model and was independently associated with longer LOS.

In a subanalysis of 254 subjects in whom pre-Fontan echocardiograms were interpreted in an echocardiographic core laboratory (Table 5), presence of at least moderate tricuspid regurgitation was independently associated with

longer LOS in multivariable models, both those that included treatment center (HR 1.72; $P < .01$) and those that excluded treatment center (HR 1.49; $P = .02$). Ventricular end-diastolic pressure and pulmonary artery abnormalities from pre-Fontan catheterization ($n = 260$) were each associated with longer LOS in univariate analysis, but not in the final multivariable model.

DISCUSSION

With advances in surgical techniques and perioperative care, the Fontan procedure surgery has low mortality in the current era.¹⁰⁻¹⁵ For patients with HLHS, and other, related, single right-ventricular anomalies, the Norwood operation performed with the RVPAS, compared with the MBTS, has been associated with a lower right-ventricular ejection fraction and more pulmonary artery distortion,

TABLE 2. Procedures performed in 104 of 323 subjects, concurrently with the Fontan operation

Procedures	n
Pulmonary arterioplasty	45
Atrioventricular valvuloplasty or repair	29
Atrial septectomy	14
Revision of superior vena cava connection	2
Aortic arch repair	5
Semilunar valvuloplasty or repair	6
Placement of permanent pacing wires	7
Pacemaker insertion	4
Resection of endocardial fibroelastosis	6
Other procedures	24

potentially heightening the risk of adverse hemodynamics after the Fontan procedure.³

In this follow-up analysis of the multicenter prospective SVR trial cohort, we found that transplant-free survival after the Fontan operation was 99.7%, with a median LOS of 10 days. Contrary to our study hypothesis, morbidity after the Fontan procedure, as indicated by post-operative LOS, was not associated with type of Norwood shunt. We found that global measures of earlier medical complexity were associated with longer LOS after Fontan surgery, including LOS at stage II, pre-Fontan procedure complications, and presence of at least moderate tricuspid regurgitation. This study is the first multicenter analysis to explore risk factors for morbidity after the Fontan procedure in patients followed prospectively from birth.

Our data are concordant with a single-center study that demonstrated no difference in LOS at the time of the Fontan procedure, by Norwood shunt type.² Our results compare favorably with those of other contemporary series that have reported mortality of 1% to 5%, and LOS of 8 to 11 days after the Fontan procedure, for various single-ventricle anomalies.¹⁰⁻¹⁵ The SVR trial cohort is

TABLE 3. List of potential predictors to include in the multivariable model ($P \leq .20$ in univariate analyses)

Predictor	P value
Center	.09
Birth weight	.16
Low birth weight (<2.5 kg)	.06
Ever had an identifiable genetic syndrome	.07
Ever had any nonsyndromic abnormalities	.13
Socioeconomic score	.2
Census tract: percentage below poverty line	.03
Norwood length of stay	.09
Age at stage II	.03
Stage II length of stay	<.001
Number of balloon angioplasties and/or stents for coarctation	.12
Number of pulmonary artery balloons and/or stent angioplasties	.17
Any pulmonary artery balloon and/or stent angioplasty	.17
Number of noncardiac surgeries	.002
Number of complications from pre-Norwood to Fontan	.006
Number of serious adverse events (through 12 mo)	.04
Any cardiopulmonary resuscitation	.15
≥Moderate tricuspid regurgitation at pre-Fontan echo	.01
Ventricular end-diastolic pressure	.11
Pulmonary artery abnormalities	.08
Weight at Fontan	.11
Type of Fontan	.14
Deep hypothermic circulatory arrest at Fontan	.18
Other concurrent cardiac surgical procedures with Fontan	.20

composed primarily of children who have HLHS, which is a risk factor for greater perioperative morbidity after the Fontan operation. In the largest report to date, of 771 consecutive patients undergoing the Fontan procedure, HLHS was present in 379 patients and was an independent predictor of longer LOS.¹⁵ In another large series that included 330 subjects who had HLHS, prolonged chest tube drainage (>14 days), which is a surrogate marker for longer LOS, was found to occur more frequently in patients who had a morphologic right ventricle.¹²

Our finding of an association between LOS at stage II and LOS at the time of the Fontan procedure has not been reported previously, although this correlation is not unexpected. Both stage II and the Fontan operation result in passive pulmonary blood flow from the systemic veins and can be affected by factors related to the integrity of the pulmonary artery vasculature and the overall performance of the single ventricle. Older age of the patient at stage II was independently associated with longer LOS. We did not identify a threshold, for age at stage II, beyond which the LOS at the time of the Fontan procedure was likely to be longer. Possibly, this finding relates to a tendency for higher-risk candidates to undergo stage II procedures later in their course of illness.

Another new observation of this study is an association between longer Fontan LOS and more complications before the Fontan operation. The number of such complications is

FIGURE 1. Kaplan-Meier curves comparing the time to hospital discharge after a Fontan operation for the 2 shunt groups (blue = modified Blalock-Taussig shunt; red = right-ventricle-to-pulmonary-artery shunt) in transplant-free survivors (logrank $P = .24$).

TABLE 4. Multivariable model for all 323 subjects, with versus without clinical center as a predictor

Variable	With center		Without center	
	Hazard ratio	P value	Hazard ratio	P value
Treatment center		<.01		
Each additional month of age at stage II			1.08	.01
Each additional day in hospital after stage II	1.02	<.01	1.02	<.01
Each additional complication from birth to Fontan	1.03	.04		
Deep hypothermic circulatory arrest at Fontan	0.64	.02		

likely a surrogate marker for overall medical morbidity. These include, but are not limited to, feeding difficulties, infections, heart failure, and frequent hospitalizations in the years preceding Fontan procedure completion.

In this study, a moderate or severe degree of tricuspid regurgitation was present in 49 subjects at the time of a pre-Fontan procedure echocardiogram and was a risk factor for longer LOS. Tricuspid valve repair or valvuloplasty ($n = 29$) was the second most common concomitant procedure that was done at the time of the Fontan procedure in SVR trial subjects. The presence of substantial tricuspid regurgitation remains a risk factor for worse outcomes through all stages of palliation.^{16,17}

Atrioventricular valve regurgitation has been reported to be a risk factor for mortality and morbidity after the Fontan operation, in both short- and long-term follow-up.^{15,17} Indeed, the association of concurrent repair of the atrioventricular valve with greater mortality and morbidity after the Fontan procedure¹⁵ likely reflects the higher risk among those who require such repair, ie, so-called confounding by indication. Tricuspid regurgitation increases the volume load of the single right ventricle and can increase the ventricular end-diastolic pressure and pulmonary artery pressure, in turn contributing to pleural effusions in the immediate postoperative period.

The use of DHCA at the time of the Fontan procedure was independently associated with shorter LOS, in models allowing for treatment center to be a predictor. This finding may be explained by a reduced incidence of systemic inflammatory response syndrome provoked by DHCA.^{18,19} Other intraoperative factors, such as longer cardiopulmonary bypass time,²⁰ and extracardiac Fontan procedure,²¹ have been associated with longer LOS in other studies, whereas fenestration and use of modified ultrafiltration have been found to be associated with shorter LOS.¹⁵ In our study,

none of these factors predicted LOS; and no pre-Fontan procedure catheterization variables or catheter-based interventions were associated with LOS. Contrary to previous reports, performance of the Fontan operation from November through May (the peak season for viral respiratory infections) was not associated with a longer LOS.^{22,23}

Our study has several limitations. We found that clinical center was a strong independent predictor of LOS after the Fontan procedure. Treatment center has been associated with outcomes in other analyses of the SVR trial, and practice pattern variation among participating sites was considerable.²⁴ Our study design did not allow for us to determine which practice differences among centers were causal. Core-laboratory interpretation of pre-Fontan procedure echocardiograms was performed for 79% subjects, ie, only those echocardiograms performed at the study center, which limited the number available for analysis. Similarly incomplete data for other risk factors, such as weight of the patient at the time of the Fontan procedure, limited our ability to evaluate their impact on LOS.

Pre-Fontan procedure cardiac catheterization was performed in 80% of subjects, but pulmonary vascular resistance was not included in the prospective data collection. We did not collect data on total number of days of chest tube drainage after the Fontan procedure. Finally, the presence of a fenestration has been linked to shorter LOS after the Fontan procedure; because most subjects (87%) in our analytic cohort had a fenestration created at the time of Fontan surgery, we could not assess the effect of fenestration on Fontan LOS.

In conclusion, in this large, prospective, multicenter trial of subjects who had HLHS and related, single right-ventricular anomalies, early transplant-free survival after the Fontan operation was nearly 100%. Despite concerns about the effect of the RVPAS on right-ventricular function

TABLE 5. Multivariable model in subjects with pre-Fontan echocardiogram ($n = 254$), with versus without treatment center as a predictor

Variable	With center		Without center	
	Hazard ratio	P value	Hazard ratio	P value
Treatment center		<.01		
Each additional month of age at stage II			1.09	.02
Each additional day in hospital after stage II	1.02	.03	1.02	<.01
At least moderate tricuspid regurgitation on pre-Fontan echocardiogram	1.72	<.01	1.49	.02

and pulmonary artery architecture, Norwood shunt type did not affect LOS. Future studies are needed to assess whether morbidity in the early period after the Fontan procedure is correlated with late Fontan morbidities.

Conflict of Interest Statement

Authors have nothing to disclose with regard to commercial support.

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Key Words: Fontan, hypoplastic left heart syndrome, Single Ventricle Reconstruction trial

APPENDIX E1

List of Candidate Predictors

General

- Treatment center
- Socioeconomic score
- Gender
- Race/ethnicity
- Anatomy

Hypoplastic left heart syndrome

Unbalanced atrioventricular canal defect

Other

- Heterotaxy (yes or no)
- Obstructed pulmonary veins defined by the use of post-natal intervention, including balloon septostomy, open atrial septectomy, or urgent Norwood procedure (yes or no)
- Gestational age
- Gestational age <37 weeks (yes or no)
- Birth weight
- Birth weight <2500 g (yes or no)
- Diagnosed with genetic syndrome or nonsyndromic abnormalities (yes or no)

Norwood Hospitalization

- Shunt in place at the end of the Norwood procedure
- Length of hospital stay

Stage II

- Age at stage II
- Length of hospital stay

Number of Serious Adverse Events (Through Age 12 Months)

From pre-Norwood to Fontan

- Number of cardiac surgeries
- Number of noncardiac surgeries

- Number of complications
- Cardiopulmonary resuscitation (yes or no)
- Extracorporeal membrane oxygenation (yes or no)
- Number of interventional catheterizations
- Balloon angioplasty/stent for coarctation (yes or no, number)
- Pulmonary artery balloon/stent angioplasty (yes or no, number)
- Coil embolization of aortopulmonary collateral vessels (yes or no, number)

Pre-Fontan

- Echocardiogram

Ventricular function

Atrioventricular valve regurgitation

- Catheterization

Pre-Fontan catheterization performed (yes or no)

Right ventricular end-diastolic pressure

Mean pulmonary artery pressure

Mean atrial pressure

Transpulmonary gradient

Pulmonary artery abnormalities

Fontan

- Month of Fontan: November to March or April to October
- Age at Fontan
- Weight at Fontan
- Type of Fontan (extracardiac or lateral tunnel)
- Fenestration (yes or no)
- Total bypass time
- Total aortic crossclamp time
- Deep hypothermic circulatory arrest (yes or no)
- Other cardiac surgical procedures concurrent with Fontan (yes or no)