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Preoperative Hemodynamics Impact the Benefit of Fenestration on Fontan Postoperative Length of Stay

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Abstract

BACKGROUND—Utilization of Fontan fenestration varies considerably by center.

OBJECTIVES—Using a multicenter Pediatric Heart Network dataset linking surgical and preoperative hemodynamic variables, the authors evaluated factors associated with use of Fontan fenestration and the impact of fenestration on post-Fontan length of stay (LOS).

METHODS—Patients 2 to 6 years old at Fontan surgery from 2010 to 2020 with catheterization<1 year prior were included. Factors associated with fenestration were evaluated

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using multivariable logistic regression adjusting for key covariates. Restrictive cubic spline analysis was used to evaluate potential cut-points for hemodynamic variables associated with longer postoperative LOS stratified by fenestration with multivariable linear regression to evaluate the magnitude of effect.

RESULTS—Fenestration was used in 465 of 702 patients (66.2%). Placement of a fenestration was associated with center (range 27%−93% use, $P < 0.0001$) and Fontan type (OR: 14.1 for lateral tunnel vs extracardiac conduit, $P < 0.0001$). No hemodynamic variable was independently associated with fenestration. In a multivariable linear model adjusting for center, a center-fenestration interaction, prematurity, preoperative mean pulmonary artery pressure (mPAP), and cardiac index, fenestration was associated with shorter hospital LOS after Fontan ($P = 0.0024$). The benefit was most pronounced at mPAP ≥13 mm Hg (median LOS: 9 vs 12 days, $P = 0.001$).

CONCLUSIONS—There is wide center variability in use of Fontan fenestration that is not explained by preoperative hemodynamics. Fenestration is independently associated with shorter LOS, and those with mPAP ≥13 mm Hg at pre-Fontan catheterization benefit the most. We propose this threshold as minimal criteria for fenestration.

Keywords

Glenn pressure; hypoplastic left heart syndrome; single ventricle

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The Fontan procedure, or inferior cavopulmonary anastomosis, represents the final stage of planned surgical palliation for all forms of functionally single ventricle heart disease. While operative mortality in the current era is low,[1] morbidity is high with a median postoperative length of stay (LOS) of 10 to 11 days and postoperative complications in 40%.[1–3] Despite being one of the most common congenital heart operations in the United States, with nearly 1,000 Fontan procedures performed per year,[4] variation exists in both the timing and techniques of the operation.

Fontan fenestration was introduced to improve postoperative outcomes for high-risk patients undergoing the Fontan procedure, including those with ventricular dysfunction, high pulmonary vascular resistance, and/or pulmonary artery distortion.[5,6] Subsequently, its acceptance has been variable with some institutions uniformly performing Fontan fenestration, even in low-risk patients, and others using fenestration sparingly. Nationally, approximately two-thirds of Fontan procedures are performed with a fenestration, but this ranges widely when evaluated by institution.[7] It is unclear whether wide-center variability reflects center-level preference or differences in preoperative patient risk. Moreover, the impact of fenestration on outcomes remains understudied at the multi-institution level.

We linked data from the Society of Thoracic Surgeons (STS) Congenital Heart Surgery Database (STS-CHSD) and the Improving Pediatric and Adult Congenital Treatment (IMPACT) cardiac catheterization registry from 7 Pediatric Heart Network (PHN) centers. Using the linked dataset, we sought to determine factors, including preoperative hemodynamic measurements, associated with Fontan fenestration and to evaluate the effect of Fontan fenestration on postoperative outcomes after accounting for preoperative hemodynamic measurements.

METHODS

STUDY POPULATION.

Seven centers were recruited through the PHN for participation in this retrospective observational cohort study. The study was approved by the institutional review board at each of the participating centers. All centers submitted data to the STS-CHSD and also to the IMPACT cardiac catheterization registry. All data were extracted locally from these databases and submitted to Cincinnati Children's Hospital for linkage and analysis. Patients were eligible for inclusion based on STS primary procedure codes that indicated fenestration status (0970–lateral tunnel [LT], fenestrated; 0980–LT, nonfenestrated; 1,000–external conduit, fenestrated; 1,010–external conduit, nonfenestrated). Those with other STS procedure codes related to total cavopulmonary connection (1,025–Fontan revision or conversion; 1,030–Fontan, other; 2,340–Fontan + atrioventricular valvuloplasty; 950–Fontan, atrio-pulmonary connection; 960–Fontan, atrioventricular connection) were excluded. Only patients having their Fontan procedure between ages 2 and 6 years and from 2010 to 2020 with cardiac catheterization data available within 12 months prior to their Fontan procedure were included. No data were available for the patients who did not meet inclusion criteria. The data were linked at 2 levels using a set of Python scripts and a SQLite database. At the first level, STS-CHSD and IMPACT data from each center were imported into a standardized format, filtered based on the variables of interest, and linked primarily through the medical record number. However, one center required the use of last name and date of birth due to the unavailability of a common unique identifier in both registries. At the second level, all databases were pulled into the SAS software and merged. It is worth noting that while 2010 was used to limit the data to the recent era, the date each center began utilizing the IMPACT registry was the primary driver of the time period utilized. This start date ranged from 2010 to 2012 for study centers.

STUDY DEFINITIONS.

Standard registry definitions from the STS-CHSD and IMPACT datasets were used including definitions for hemodynamic parameters,[8] procedures, postoperative LOS, and major complications, which include renal failure, neurologic injury or deficit, arrhythmia requiring pacemaker, unplanned reintervention, or mechanical circulatory support.[9] Postoperative mortality, as defined per the STS includes death during hospitalization or within 30 days of Fontan if discharged.[10]

STATISTICAL ANALYSIS.

Variables are presented as median (IQR) or count with percent of total unless otherwise specified. Patient characteristics and outcomes by fenestration were compared using the Wilcoxon rank sum test or chi-squared test. Center variation was compared using the Kruskal-Wallis test or chi-squared test. Factors associated with fenestration were evaluated using multivariable logistic regression. Full model covariates, determined a priori, included center, ventricular dominance, Fontan type (LT vs extracardiac conduit), age at Fontan, sex, race, and hemodynamic variables. Exploratory analysis using restrictive cubic splines was performed to establish potential cut-points for hemodynamic variables associated with longer postoperative LOS stratified by fenestration placement. Post-Fontan LOS was analyzed by fenestration status across hemodynamic variables using nonparametric ANOVA. Factors associated with LOS, assuming a log-normal distribution and the above-mentioned covariates, were evaluated using multivariable linear regression. Fontan type was not included in the full model due to collinearity with fenestration, but all other covariates were included. The distribution of LOS was visually inspected against fitted lognormal curve and modeled using the Genmod procedure with log link and normal distribution. Scaled Pearson chi-squared/degrees of freedom was used to assess model fit. Effect estimates were back transformed (exponentiated) and interpreted as % increase in outcome per unit increase in independent variables. Only significant factors were included in the final model are presented. A *P* value <0.05 was considered significant, but interval estimates were not adjusted for multiple comparisons and should be interpreted with caution. Analysis was done in SAS 9.4 (SAS Institute).

RESULTS

The cohort included 704 patients from 7 centers including 467 (66.3%) with fenestration (Central Illustration). Demographic, diagnostic, and hemodynamic characteristics, stratified by fenestration status, are presented in Table 1. Median age at Fontan was 3.4 years (IQR: 2.7–4.2) years, and median time between cardiac catheterization and Fontan was 67 days (IQR: 18–141) days.

FACTORS ASSOCIATED WITH FENESTRATION.

In univariable analysis, fenestrated (Fen) patients were older, larger, less likely to be of Hispanic ethnicity, more likely to have right ventricular dominance, and more likely to have a LT Fontan when compared to the nonfenestrated (non-Fen) patients (Table 1). There were no univariable differences in pre-Fontan hemodynamic measurements between groups. There was variation between centers in timing of catheterization and Fontan as well as use of fenestration (Table 2). The center-level median age and weight at Fontan ranged from 2.4 to 4.2 years and 12.6 to 15.3 kg, respectively. The percentage of Fen varied across centers from 27% to 93%. Due to co-linearity between mean pulmonary artery pressure (mPAP), ventricular end-diastolic pressure (EDP), and pulmonary vascular resistance index (PVRi), separate multivariable models were created to assess factors associated with Fontan fenestration. Forest plots for these models are shown in Figure 1. Center and LT Fontan were associated with fenestration, but ventricular dominance, mPAP, EDP, and PVRi were not.

OPERATIVE AND POSTOPERATIVE COMPARISONS.

Median postoperative LOS was 9 (IQR: 7–13) days, ranging from 7 to 12 days by center. Overall, major postoperative complications occurred in 19 (4.9%) and readmission within 30 days occurred in 110 (16.0%). There were 2 postoperative/30-day deaths (0.4%). Univariable comparison of outcomes between the non-Fen and Fen groups can be seen in Table 3. Notably, perfusion and cross clamp times were longer in the Fen patients, while there was no difference in the frequency of major complication, the non-Fen group more frequently developed chylothorax, while the Fen group more frequently had arrhythmias postoperatively. The postoperative LOS was significantly shorter (median 8 [IQR: 7–12] days vs 10 [IQR: 7–14] days, $P = 0.006$) in the Fen group. In a multivariable linear model adjusting for center, a center-fenestration interaction, prematurity, mPAP, and cardiac index, fenestration remained significantly associated with a shorter hospital LOS after Fontan (Table 4). Exploratory analysis using restrictive cubic spline regression demonstrated the hospital LOS was shorter in Fen patients throughout the range of pre-Fontan mPAPs with a paucity of data at the high and low ends resulting in wider CIs. A pre-Fontan mPAP of ≥13 mm Hg was associated with the greatest difference in postoperative LOS (Figure 2). Similar analyses for pre-Fontan EDP, PVRi, and cardiac index did not reveal strong cut points.

The mPAP was ≥13 mm Hg in 184/661 (27.8%) patients with available data. Of those with a mPAP ≥13 mm Hg, 126 (68.4%) had a fenestration placed. In a stratified comparison of those with a mPAP <13 mm Hg, LOS was similar between the non-Fen (9 [IQR: 7–13] days) and Fen (8 [IQR: 7–11] days) groups ($P = 0.25$) but was significantly longer in the non-Fen group when mPAP was ≥13 mm Hg (12 [IQR: 8–16] days vs 9 [IQR: 7–12] days, $P = 0.01$) (Figure 3). LOS >14 days was likewise similar in frequency between non-Fen and Fen groups when mPAP was <13 mm Hg (17.6% vs 13.6%, $P = 0.27$) but significantly more common in the non-Fen group when mPAP was ≥13 mm Hg (34.5% vs 16.7%, $P = 0.007$).

DISCUSSION

This study has demonstrated the short-term benefit of Fontan fenestration in reducing postoperative LOS. While this benefit was seen across the spectrum of patients, it was most notable when the preoperative mPAP or Glenn pressure was 13 mm Hg or higher. Our study is unique in that it is the first multicenter study that includes pre-Fontan hemodynamic measurements when comparing outcomes based on fenestration of the Fontan. While cardiac catheterization is frequently obtained prior to the Fontan procedure, we also demonstrated in this study that the hemodynamic data are not utilized similarly across institutions when determining fenestration placement.

Our findings are similar to those of prior studies in identifying variation in the timing of the Fontan procedure among centers. Wallace et al[1] described variation in age and weight in 2011 using data from the STS-CHSD. They demonstrated even greater variation when including 68 centers with median age ranging from 1.7 to 4.8 years and median weight ranging from 10.5 to 16.1 kg. As the Fontan procedure is a semielective operation in nearly all cases, this variation exceeds differences in patient characteristics and seasonal Fontan procedure timing, often aimed at reducing exposure to viral respiratory infections,[11–13] and indicates a lack of consensus on best practices for optimal short- and long-term outcomes. Our study uncovered another variation in practice that could likely benefit from standardization, ie, timing of pre-Fontan catheterization in relation to the Fontan procedure. Centers varied in the median time between these 2 procedures from 5 to 165 days. While some have advocated for using cardiac magnetic resonance imaging instead of cardiac catheterization prior to Fontan,[14,15] cardiac catheterization was still performed in most of those enrolled in the Single Ventricle Reconstruction trial.[16] Our study was not designed to evaluate indications for catheterization or optimal timing, but the discrepant timing suggests further study is warranted.

We found similar overall rates to prior studies for the use of fenestration at the Fontan procedure. Prior studies evaluating the PHN cross-sectional study cohort[17] and the Virtual Pediatric Systems database[7] have demonstrated fenestration placement in 64 to 67%, similar to our reported rate (66%). Evidence to support fenestration in the form of a prospective randomized trial was published in 2002. This single-center trial enrolled 49 patients and demonstrated that in standard-risk patients, fenestrated patients had decreased pleural drainage, decreased postoperative LOS, and fewer additional procedures after Fontan.[18] Since that time, multiple authors have published single-center case series with the conclusion that routine Fontan fenestration is unnecessary.[19–21] The vast differences in the rate of fenestration between centers found in our study and priors[7,17] suggest that no definitive evidence or consensus opinion exists. In the absence of these, surgeon preference and local practice likely dictate fenestration placement.

One novelty of this study was the method of data capture, which utilized the registry submission processes and allowed rapid acquisition of data for a large number of patients from multiple centers and different databases. The junction of catheter data and surgical data allowed robust evaluation of hemodynamic parameters associated with operative outcomes. The absence of any association between hemodynamic measurements and fenestration speaks to the lack of prior published work in this area. We identified the mPAP as the best measure of fenestration benefit. This is likely because mPAP accounts for EDP, PVRi, and Glenn, or branch pulmonary artery stenosis. Our data have identified a subset of patients, accounting for over one-quarter of the study population, likely to derive the greatest short-term benefit with reduced LOS from fenestration placement at the time of Fontan. Based on prior published data, this decreased LOS is related to decreased chest tube drainage and duration.[18] While fenestration with a mPAP <13 mm Hg may continue to be preferred by some providers, we believe a mPAP ≥ 13 mm Hg should be a strong indication for fenestration and hope these data will reduce variation in Fontan fenestration practices.

STUDY LIMITATIONS.

This study is limited to the data available in the IMPACT and STS databases. While it adds hemodynamic data to the evaluation of Fontan fenestration, the reasoning behind surgical decision-making for individual patients is complex, and not all the data contributing to that decision are included. Due to the data extraction platform design as well as institutional review board restrictions, patients not meeting inclusion criteria were removed prior to data transfer for this study. Therefore, no counts or information is available to compare those meeting inclusion criteria and those who did not. As we did not include patients undergoing Fontan with atrioventricular valve repair or Fontan revisions, this study focused on a lower-risk population. Additionally, due to co-linearity between the LT Fontan and fenestration in our cohort, we could not include the type of Fontan in our multivariable model. Finally, not all data variables were available for all patients. Our study design only assessed the short-term benefits of Fontan fenestration. Long-term follow-up of otherwise similar patients with and without fenestration is needed to assess the impact of this technique on long-term Fontan morbidities, like Fontan-associated liver disease, stroke, and Fontan failure.

CONCLUSIONS

The Fontan procedure remains highly variable by institution, not only in timing but also in use of the Fontan fenestration. Preoperative hemodynamics do not explain the variation between institutions in the use of fenestration, as there are no consistent hemodynamic criteria for fenestration across institutions. While fenestration placement reduces postoperative LOS across the range of patients, it is patients with a mPAP of ≥13 mm Hg at pre-Fontan catheterization that demonstrate the greatest reduction in LOS with fenestration. We would propose a mPAP ≥13 mm Hg as minimal criteria for fenestration.

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ABBREVIATIONS AND ACRONYMS

EDP	end-diastolic pressure
Fen	fenestrated Fontan group
LOS	length of stay
LT	lateral tunnel
LV	left ventricular
mPAP	mean pulmonary artery pressure
non-Fen	nonfenestrated Fontan group
PVRi	pulmonary vascular resistance index
RV	right ventricular
STS	Society of Thoracic Surgeons

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PERSPECTIVES

COMPETENCY IN MEDICAL KNOWLEDGE 1:

Fontan fenestration does not have consistent criteria, including preoperative hemodynamic measurements, for use across institutions.

COMPETENCY IN MEDICAL KNOWLEDGE 2:

Postoperative length of stay is reduced with Fontan fenestration, particularly in those with higher mean pulmonary artery pressure.

COMPETENCY IN PATIENT CARE:

Fontan fenestration should be strongly considered in all patients with a pre-Fontan mean pulmonary artery pressure of ≥13 mm Hg.

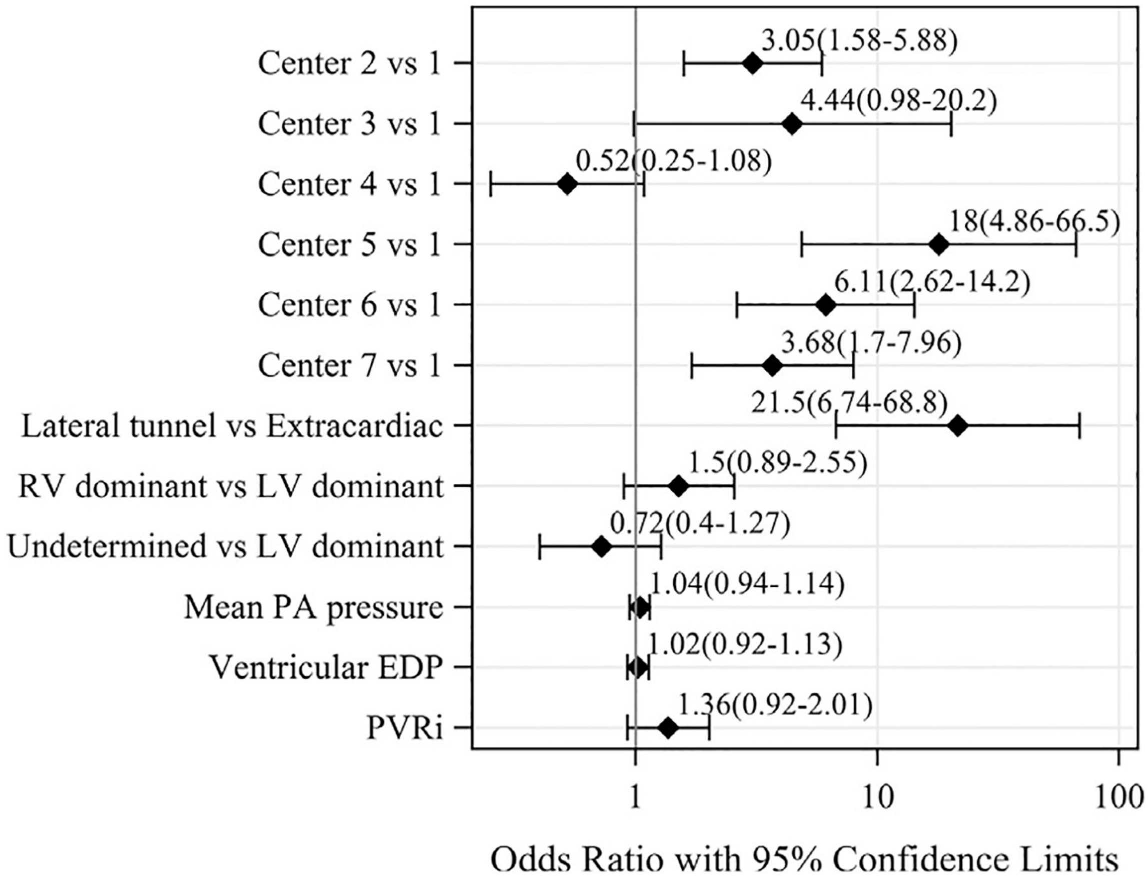


FIGURE 1.

Forest Plots of Factors Associated With Fontan Fenestration

Forest plots generated by multivariable logistic regression for factors associated with Fontan fenestration. Additional factors included in the model but not shown are age at Fontan, sex, race, pulmonary vascular resistance index, and cardiac index. Due to co-linearity, separate models were created for mean pulmonary artery pressure, ventricular end diastolic pressure, and pulmonary vascular resistance index. The OR (◆) and 95% CIs (lines) are depicted with center and Fontan type (lateral tunnel) associated with fenestration. EDP = end diastolic pressure; LV = left ventricle; PA = pulmonary artery; PVRi = pulmonary vascular resistance index; RV = right ventricle.

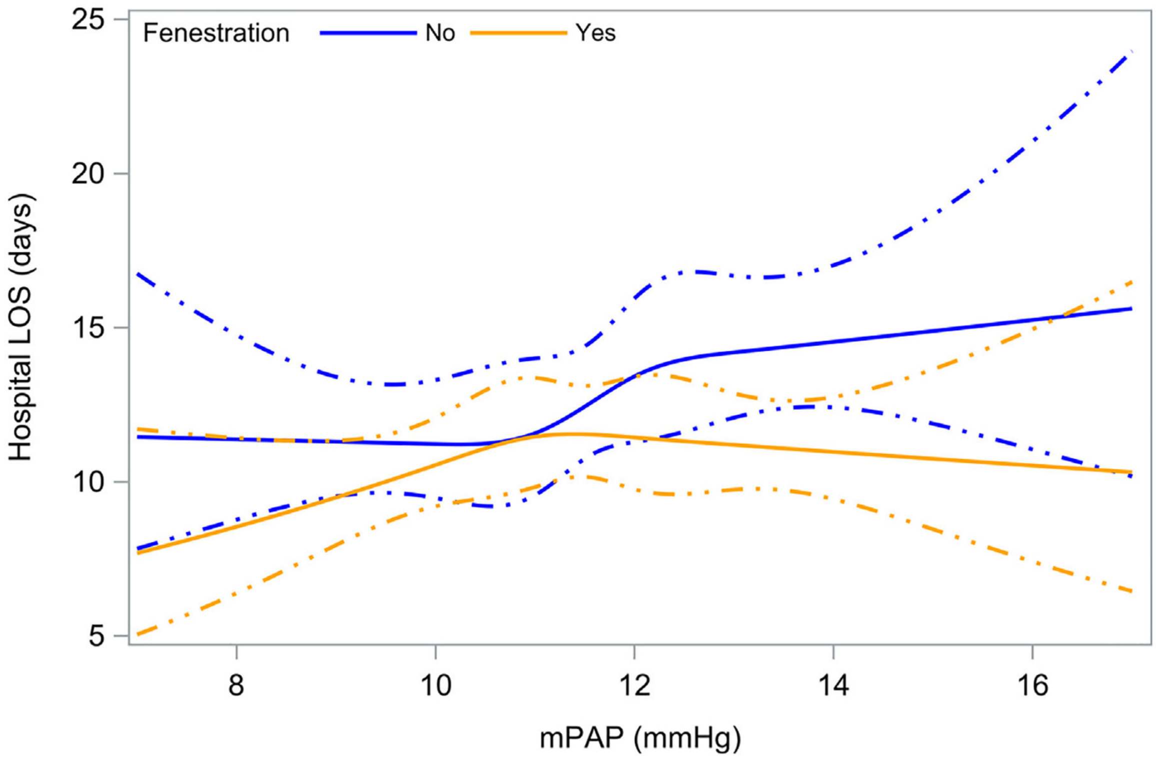


FIGURE 2.

Comparison of LOS Across mPAPs by Fenestration

Restrictive cubic spline model demonstrating the postoperative LOS across the range of pre-Fontan mPAPs for those having a fenestration placed (orange) and those not having a fenestration placed (blue) with 95% CI displayed. LOS was shorter throughout the range of mPAPs with fenestration, but the greatest divergence was seen when mPAP was ≥13 mm Hg. LOS = length of stay; mPAP = mean pulmonary artery pressure.

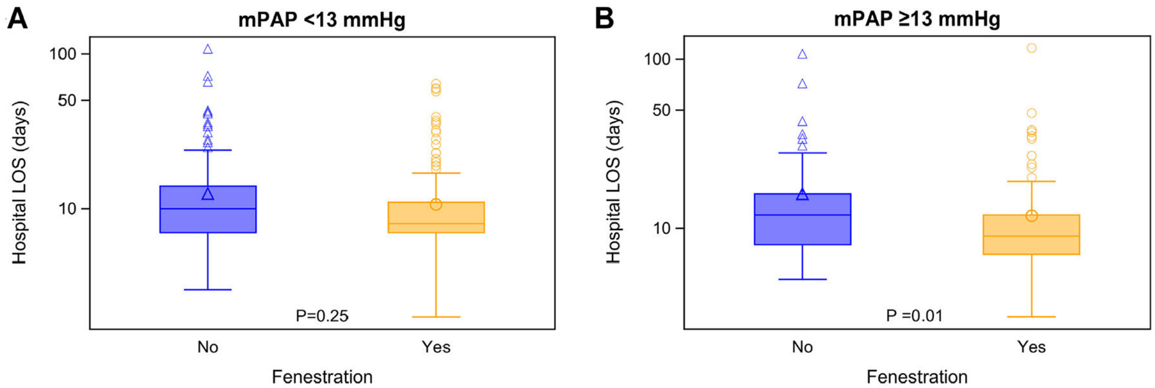
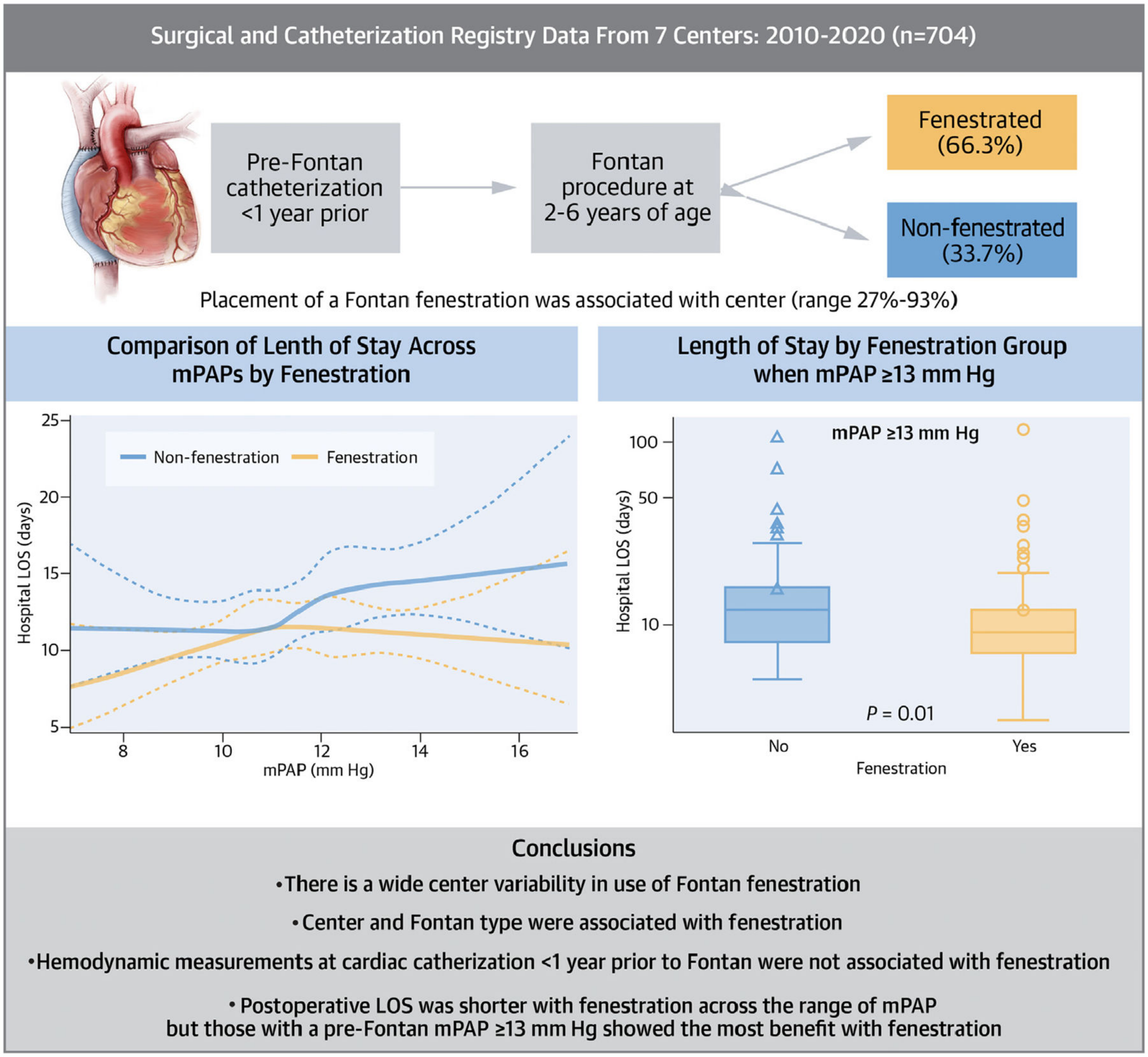


FIGURE 3.

LOS by Fenestration Group Stratified by mPAP

Box and whisker plots demonstrating the post-Fontan LOS in days (log scale) for those with (orange) and without (blue) a fenestration placed at the time of Fontan (A) when mPAP was <13 mm Hg and (B) when mPAP was ≥13 mm Hg. Boxes represent the interquartile range and whiskers highest/lowest observation within fence (the interquartile ±1.5*IQR). Symbols (triangle and circle) inside the boxes represent the mean. Median LOS in fenestrated patients was not significantly lower than in nonfenestrated patients (8 vs 9 days, $P = 0.25$) (A) when mPAP was <13 mm Hg. When mPAP was ≥13 mm Hg median LOS was significantly shorter in fenestrated patients (9 vs 12 days, $P = 0.01$). LOS = length of stay; mPAP = mean pulmonary artery pressure.



CENTRAL ILLUSTRATION.

Preoperative Hemodynamics Impact the Benefit of Fenestration on Fontan Postoperative Length of Stay

Among 704 patients undergoing the Fontan procedure, 66.7% were fenestrated and 33.7% were nonfenestrated Fontan procedures. Only center and Fontan type (lateral tunnel vs extracardiac conduit) were associated with fenestration, while hemodynamic measurements at cardiac catheterization <1 year prior to Fontan were not associated with fenestration. Postoperative LOS was shorter with fenestration across the range of mPAPs, but those with a pre-Fontan mPAP ≥13 mm Hg showed the most benefit with fenestration (median LOS 9 vs 12 days, $P = 0.01$). EDP = end-diastolic pressure; LOS = length of stay; mPAP = mean pulmonary artery pressure; PVRi = pulmonary vascular resistance index.

TABLE 1

Cohort Characteristics

	N	Overall	Non-Fen	Fen	*P* Value
Age at Fontan (y)	704	3.4 (2.7–4.2)	3.9 (3.2–4.6)	3.1 (2.5–3.9)	**<0.0001**
Height (cm)	702	95 (89–101)	98.3 (93–103)	93 (88–99)	**<0.0001**
Weight (kg)	704	14 (12.6–15.7)	14.7 (13.4–16.4)	13.5 (12.2–15.5)	**<0.0001**
Female	704	261 (37.1%)	91 (38.4%)	170 (36.4%)	0.6
Caucasian race	702	522 (74.4%)	182 (77.1%)	340 (73.0%)	0.23
Hispanic ethnicity	543	71 (13.1%)	40 (21.5%)	31 (8.7%)	**<0.0001**
Premature birth	695	93 (13.4%)	33 (14.0%)	60 (13.0%)	0.92
Genetic syndrome	673	114 (16.9%)	42 (18.8%)	72 (16.0%)	0.36
Ventricular morphology	704				**0.02**
Dominant RV		259 (36.8%)	72 (30.4%)	187 (40%)	
Dominant LV		205 (29.1%)	70 (29.5%)	135 (28.9%)	
Undetermined		240 (34.1%)	95 (40.1%)	145 (31%)	
Ventricular EDP (mm Hg)	588	8 (7–10)	8 (7–10)	8 (7–10)	0.2
mPAP (mm Hg)	594	11 (10–13)	11 (10–13)	11 (10–13)	0.17
PVRi (WU/m^2)	673	1.39 (1–1.8)	1.4 (1–1.7)	1.4 (1–1.8)	0.83
Cardiac Index (L/min/m^2)	631	4.7 (3.9–5.7)	4.7 (4–5.6)	4.7 (3.9–5.7)	0.85
Fontan type					
Extracardiac conduit	694	497 (71.6%)	225 (97%)	272 (58.9%)	**<0.0001**
Lateral tunnel		197 (28.4%)	7 (3.0%)	190 (41.1%)	

Values are median (IQR) or n (%). Due to missing data, the n used for each variable is shown. Comparisons by Wilcoxon rank sum test or chi-square test. **Bold** indicates a significant *P* value.

EDP = end-diastolic pressure; Fen = fenestrated; LV = left ventricle; Non-Fen = nonfenestrated; PA = pulmonary artery; PVRi = pulmonary vascular resistance index; RV = right ventricle.

TABLE 2

Center Variation in Pre-Fontan and Fontan Practice

	Center 1	Center 2	Center 3	Center 4	Center 5	Center 6	Center 7	*P* Value
n (%)	66 (9.4%)	152 (21.7%)	86 (12.3%)	107 (15.2%)	121 (17.2%)	77 (11%)	93 (13.2%)	-
Cath to Fontan time (d)	73 (36–133)	102 (64–160)	49 (27–88)	165 (116–227)	5 (2–39)	41 (9–84)	50 (10–130)	**<0.001**
Fen	24 (36.4%)	102 (67.1%)	80 (93%)	29 (27.1%)	112 (92.6%)	52 (67.5%)	66 (71%)	**<0.001**
Age at Fontan (y)	3.7 (3.1–4.2)	4.2 (3.3–5)	2.4 (2.1–3)	4.2 (3.6–4.6)	2.7 (2.3–3)	3.1 (2.7–3.6)	3.5 (3–4)	**<0.001**
Weight at Fontan (kg)	14.5 (13–15.5)	15.1 (12.9–17.1)	12.8 (11.6–14)	15.3 (14.1–17.2)	12.6 (11.8–13.7)	13.9 (12.6–15)	14.2 (13–15.7)	**<0.001**
Postoperative LOS (d)	9 (7–12)	7 (6–9)	8 (7–14)	12 (10–15)	9 (7–12)	10 (8–14)	8 (7–11)	**<0.001**

Values median (IQR) or n (%). Comparisons by Kruskal-Wallis test or chi-square test. **Bold** indicates a significant *P* value.

Fen = fenestrated group; LOS = length of stay.

TABLE 3

Operative and Postoperative Comparisons

	Non-Fen (n = 238)	Fen (n = 483)	*P* Value
Perfusion time (min)	0 (0–75)	83 (63–110)	**<0.0001**
Cross clamp time (min)	0 (0–20)	38 (0–61)	**<0.0001**
Hospital LOS (d)	10 (7–14)	8 (7–12)	**0.006**
Postop major complications	6 (3.0%)	13 (6.7%)	0.093
Reoperation or intervention	11 (4.6%)	21 (4.4%)	0.87
Pleural effusion	16 (6.7%)	22 (4.6%)	0.22
Chylothorax	13 (5.5%)	8 (1.7%)	0.004
Arrhythmia	8 (3.4%)	39 (8.1%)	0.016
30-d readmissions	46 (19.7%)	64 (14.1%)	0.093
Operative/30-d mortality	0 (0.0%)	2 (0.5%)	0.56

Values are median (IQR) or n (%). Comparisons by Wilcoxon rank sum test or chi-square test. **Bold** indicates a significant *P* value.

Fen = fenestrated group; LOS = length of stay; Non-Fen = nonfenestrated group; Postop = postoperative.

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TABLE 4

Multivariable Analysis for Factors Associated With LOS

	β	Effect Size in Original Scale (95% CI)	*P* Value
Fenestration	-	-	**0.0024**
Center	-	-	**<0.0001**
Center*Fen interaction	-	-	**0.0017**
Prematurity	1.77	1.52–2.06	**<0.0001**
MPAP	1.13	1.09–1.16	**<0.0001**
Cardiac index	0.92	0.87–0.97	**0.002**

Results of multivariable linear regression model for factors associated with post-Fontan length of stay. **Bold** indicates a significant *P* value. Due to the center-fenestration interaction, effect sizes for these variables are not presented.

β = regression coefficient; Fen = fenestration; mPAP = mean pulmonary artery pressure.