



## Emergency department utilisation and critical readmission in patients with Fontan circulation

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## Original Article

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**Abstract**

**Background:** We aimed to conduct a multi-centre study characterising emergency department utilisation and critical readmissions experienced by children with Fontan circulation. **Methods:** We conducted a retrospective review of children who underwent the Fontan operation at three institutions (i.e., centres A, B, and C) between 2009 and 2014, with follow-up through December 2015. Multi-variable analyses were performed to determine factors associated for emergency department utilisation within 1 year of surgery, emergency department utilisation at any time following surgery, or critical readmission (defined as admission to ICU, operating room, or cardiac catheterisation). **Results:** We reviewed 297 patients, of which 147 patients (49%) had 607 emergency department encounters. Forty-six patients (15%) required 71 critical readmissions. Multi-variable analyses revealed centre C ( $p = 0.02$ ) and post-operative hospitalisation  $\geq 14$  days ( $p = 0.03$ ) to be significantly associated with emergency department utilisation within 1 year, whereas centre B ( $p < 0.001$ ), post-operative hospitalisation  $\geq 14$  days ( $p = 0.002$ ), and African-American/Black race ( $p = 0.04$ ) were significantly associated with critical readmission. **Conclusions:** In this multi-centre study, nearly half of patients with Fontan circulation received emergency department care, often presenting with high disease acuity requiring readmission. Emergency department utilisation and need for critical readmission were independently influenced by the centre at which surgery was performed, prolonged post-operative hospitalisation, and racial background. These data could help guide quality improvement efforts aimed at reducing morbidity in this unique patient population.

Children born with a functional single cardiac ventricle commonly require a series of three surgical procedures during the first 2–4 years of life to provide the opportunity for long-term survival. Between these operations, children are at risk for complications related to their fragile anatomy, many of which can be life-threatening.<sup>1–4</sup> Consequently, emergency department utilisation during the inter-stage periods prior to the third surgical stage has been shown to be high and associated with significant morbidity.<sup>1,5</sup> In one recent study, compared to other children with CHD, children with single ventricle anatomy have increased mortality and unplanned readmission to the ICU, even up to a year after their initial surgical intervention.<sup>6</sup>

To our knowledge, little data have been published on emergency department utilisation of children with single ventricle anatomy after their third and, in most cases, final surgical stage referred to as the completion Fontan procedure (excluding the need for later Fontan revisions, orthotopic heart transplantation, or surgical procedures to address residual defects). Though the Fontan operation is an essential procedure for most children with single ventricle anatomy, the resulting cardiovascular circulation is complex and associated with several unique complications.<sup>7</sup> Reports on the emergency department presentation of children with CHD thus far have focused mainly on children with undiagnosed CHD<sup>8</sup> or heterogeneous groups of children with known CHD in which only a small cohort has Fontan circulation.<sup>9</sup> To our knowledge, no study to date has examined emergency department utilisation specific to patients with this complex anatomy and physiology. Similar to our previous work in patients with single ventricle anatomy,<sup>1,5</sup> we hypothesised that after the Fontan operation, emergency department use will be frequent, and children will present with high acuity compared to other common emergency department diagnoses. We aim to describe the frequency, indications, and factors associated with emergency department utilisation in children with Fontan circulation using a multi-centre dataset. We also aim to describe the frequency of and factors associated for critical readmission from the emergency department in this fragile patient population.

## Methods

This multi-centre retrospective study was conducted at three Midwest tertiary care referral centres: Children's Hospital of Wisconsin, Milwaukee, WI; Children's Hospital of Michigan, Detroit, MI; and Riley Hospital for Children at Indiana University Health, Indianapolis, IN in the United States of America. The study was approved by the institutional review boards at all participating centres.

All patients who underwent a completion Fontan operation for single ventricle anatomy between January 1, 2009 and December 31, 2014 were identified via the cardiovascular surgical databases at the participating institutions. Anatomic diagnoses were based on echocardiographic findings and operative reports. Patients who died post-operatively prior to discharge were excluded. The intraoperative and post-operative medical records for included patients were reviewed, with follow-up through December 31, 2015.

Chart review with data collection was performed by junior co-investigators at each site after training by the site principal investigator. Chart review was performed by unblinded reviewers using a data collection tool that was standard across sites and included age, weight, sex, cardiac lesion, comorbidities, operative procedures prior to the completion Fontan procedure, operative details (e.g., type of Fontan procedure; presence of fenestration; additional surgical procedures during the Fontan operation such as pulmonary arterioplasty, atrial septectomy, tricuspid valvuloplasty, repair of superior vena cava stenosis, aneurysm repair, aortic valve repair, and Maze procedure). We also recorded post-operative complications, durations of ICU and hospital stay, discharge medications, and discharge echocardiogram findings. Data were also recorded for any emergency department visits post-discharge including chief complaint, admitting diagnosis, treatment, and disposition. Chief complaints were recorded as documented in the medical record and then categorised to be consistent with our previous work.<sup>1</sup> The primary author then reviewed the categorisation for each patient and new categories were created if deemed necessary after agreement by the three site principal investigators. Critical readmissions were defined as patients who required transfer directly to the operating room, cardiac catheterisation suite, or ICU from the emergency department. The principal investigator at each site audited charts periodically to ensure data accuracy and integrity.

## Statistical analysis

Data are represented using descriptive statistics with medians with 25th percentiles and 75th percentiles for continuous variables and absolute counts with percentages for categorical variables. Surgical data from each of the three participating study centres (designated as centres A, B, and C for purposes of the analysis) were compared using  $\chi^2$  tests and Kruskal–Wallis rank tests as appropriate for individual variables. We performed a bivariate comparison of variables in children who required emergency department visits within 1 year of surgery to patients who had no emergency department visits during this time period using Mann Whitney *U* tests,  $\chi^2$  tests, and Fisher's exact test as appropriate for individual variables. We performed this analysis with the rationale that all patients included in the study had at least 1 year of follow-up data available. Multi-variate regression analysis was then performed to identify factors associated with emergency department visitation within 1 year of the Fontan operation. Variables with *p*-values < 0.2 on bivariate analysis were considered for inclusion in our multi-variable logistic

regression models. Centre was included in these models as a fixed (main) effect, with centre A being used as the reference centre. Linearity in the logit was examined for continuous variables prior to model-building; those with evidence of non-linearity were converted to categorical variables. Variables with *p*-values < 0.05 after multi-variable analysis were then identified as independent factors associated for emergency department use within 1 year of Fontan palliation. Similar analyses were performed to determine independent factors associated with emergency department utilisation or critical readmission at any time following Fontan operation. Dunnett's corrections were used for pairwise comparisons to reference groups, to control for type I error rates. Collinearity among variables in the multi-variable models was assessed by variance inflation factors. All statistical analyses were performed using STATA version 15.1 and SAS v9.4 (SAS Institute, Cary, North Carolina, United States of America).

## Results

We identified 297 patients who underwent completion Fontan operation and survived to hospital discharge between 2009 and 2014. Median age at the time of Fontan operation was 2.9 years (range: 0.6–14.8 years), and median duration of follow-up was 44 months (range: 12–85). Variation in surgical practices and post-operative anticoagulation use across the three participating centres are provided in Table 1.

Notable differences between centres include most patients at centre A underwent the hemi-Fontan procedure as their second stage surgery and a lateral tunnel Fontan procedure, while nearly all patients at centre B underwent the Glenn procedure as their second stage surgery and an extra-cardiac Fontan procedure; age at Fontan operation differed significantly across centres, but duration of available follow-up was statistically similar; and nearly all patients at the three participating centres were discharged on aspirin for thrombus prophylaxis, whereas use of adjunctive prophylaxis with warfarin only occurred at centre A and centre B.

During the 5-year study period, 147 patients (49%) required 607 emergency department visits (median: 3 visits; range: 1–28). Patient disposition following each emergency department encounter is summarised in Figure 1.

Eight-seven patients required 220 admissions, with 46 of these patients requiring 71 critical admissions. One patient suffered a cardiac arrest at home and died in the emergency department; this patient was included in the analysis of critical admissions. The most common chief complaints and indications associated with emergency department visits and critical readmission, respectively, are listed in Table 2.

Children most commonly presented with respiratory complaints (27%), gastrointestinal complaints (17%), or fever (15%). The most common chief complaint for critical readmission was bronchiolitis/viral respiratory illness. Other notable critical readmission diagnoses include toxic colitis (*n* = 1), Burkitt's lymphoma (*n* = 1), adrenal crisis (*n* = 1), and femur fracture (*n* = 1). Thromboembolic complications were associated with two admissions, both of which were cerebrovascular insults – one patient suffered an acute left middle cerebral artery stroke necessitating ICU admission while another patient was found to have a subacute ischaemic insult that prompted admission to the cardiology ward. Both patients were discharged on aspirin therapy but not warfarin therapy.

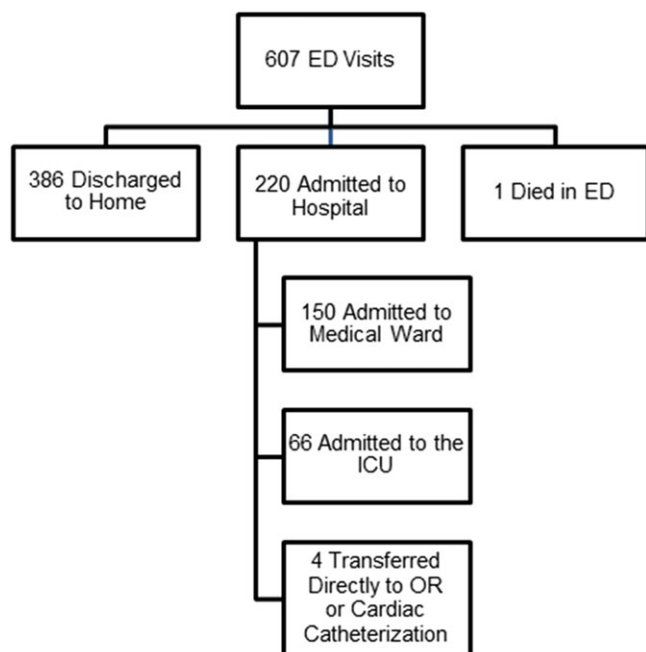
Variation in emergency department utilisation and critical readmissions are illustrated in Supplementary Figure 1. Emergency department utilisation and critical readmissions are reported across

**Table 1.** Surgical procedures and post-Fontan anticoagulation practices surrounding patients with single ventricle anatomy at the three participating study centres

Characteristics	Centre A (n = 88)	Centre B (n = 145)	Centre C (n = 64)	p-Value
Stage 1 procedure (%)				0.053
Norwood	39 (44)	74 (51)	21 (33)	
Shunt only	27 (31)	24 (17)	19 (30)	
Other	16 (18)	37 (26)	20 (31)	
None	6 (7)	10 (7)	4 (6)	
Stage 2 procedure (%)				<0.001
Glenn	7 (8)	143 (99)	26 (41)	
Hemi-Fontan	77 (88)	2 (1)	38 (59)	
Other	2 (2)	0 (0)	0 (0)	
None	2 (2)	0 (0)	0 (0)	
Stage 3 procedure (Fontan) (%)				<0.001
Lateral tunnel	83 (94)	6 (4)	35 (55)	
Extra-cardiac	5 (6)	139 (96)	29 (45)	
Age at procedure (years)	2.3 (2.1–2.8)	3.2 (2.7–3.7)	2.8 (2.0–3.4)	<0.001
Fenestration (%)	75 (85)	144 (99)	51 (80)	<0.001
Additional procedure(s) (%)*	14 (16)	46 (32)	28 (44)	0.001
> 3 unique surgical procedures (%)**	25 (28)	7 (5)	5 (8)	<0.001
Discharge anticoagulation (%)				
Aspirin	87 (99)	139 (96)	63 (98)	0.46
Warfarin	72 (82)	144 (99)	0 (0)	<0.001
Duration of follow-up (months)	49.0 (26.9–67.0)	44.4 (29.4–65.1)	35.9 (21.6–55.9)	0.12

\*Additional concomitant surgical procedure at the time of Fontan operation

\*\*More than three unique surgical procedures before and including Fontan operation

**Figure 1.** Disposition of Fontan patients after presentation to the Emergency Department. ED, emergency department; ICU, intensive care unit; OR, operating room.

the three centres, such that patients from centre C were more likely to utilise emergency department services within 1 year of discharge and at any time following Fontan operation, but not more likely to require critical readmission. Conversely, patients from centre B were not more likely to utilise emergency department services but were most likely to require critical hospital admissions.

Bivariate comparisons of patients who did and did not utilise the emergency department within 1 year of Fontan palliation are provided in Table 3. There was significant variation in emergency department encounters across racial backgrounds, with African-American/Black patients more commonly utilising the emergency department. Emergency department encounters were also significantly more common in patients with prolonged post-operative hospitalisations (i.e., post-operative hospitalisations greater than or equal to 14 days) and patients not discharged on warfarin therapy. Patients with prolonged post-operative hospitalisation were also more likely to suffer post-operative complications, as illustrated in Figure 2. For example, patients with prolonged post-operative hospitalisations experienced significantly more chylothoraces, post-operative infections, neurologic insults, and other less common complications such as unplanned cardiovascular procedures not for bleeding (n = 3), extracorporeal membrane oxygenation (n = 2), and renal failure require dialysis or peritoneal drain placement (n = 2) significantly more frequently as compared to patients discharged within 14 days of their Fontan operation.

**Table 2.** Most frequent chief complaints and indications for critical readmission for patients presenting to the emergency department after their Fontan operation

Chief complaint	n
Respiratory	165
Bronchiolitis/viral respiratory illness	99
Respiratory distress/hypoxia	63
Plastic bronchitis	3
Gastrointestinal	105
Abdominal pain/distension/constipation	37
Vomiting/diarrhea	68
Fever	89
Trauma/Injury/musculoskeletal*	60
Arrhythmia	20
Neurologic complaint**	19
Congestive heart failure/swelling	18
Ear pain/ear infection	15
Chest pain	14
Bleeding***	12
<b>Indication for critical readmission</b>	<b>N</b>
Bronchiolitis/viral respiratory illness	10
Congestive heart failure	9
Pleural effusion	9
Acute kidney injury/dehydration	9
Pneumonia/respiratory distress/hypoxia	9
Tachyarrhythmia	8
Mediastinitis	5
Plastic bronchitis	3
Sepsis/shock	3
Stroke/seizures	2

\*Chief complaint includes motor vehicle accident, lacerations, falls, and extremity injury

\*\*Includes seizures, ataxia, focal neurologic deficits, and syncope

\*\*\*Includes epistaxis, incisional bleeding, hemoptysis, and gastrointestinal bleed

Bivariate analyses of patients with and without emergency department encounters at any time after the Fontan operation are presented in Supplementary Table 1. Similar to the comparisons of patients who utilised the emergency department within 1 year, racial background, prolonged post-operative hospitalisation, and not being discharged on warfarin therapy were associated with emergency department utilisation at any time point following the Fontan operation. Additionally, patients who were discharged on three diuretic medications (e.g., furosemide, spironolactone, and chlorothiazide) were more likely to have emergency department encounters.

Post-operative hospitalisation greater than or equal to 14 days and discharge with three diuretic medications were also significantly more common in patients who required critical readmission, but there was no significant difference in the proportion of patients discharged on warfarin therapy and there was less variation in critical admissions among the different racial backgrounds as shown in Table 4. Also, patients who received an extra-cardiac

Fontan and patients not discharged on aspirin therapy were significantly more likely to require critical readmissions.

Multi-variable analyses of factors associated with emergency department utilisation within 1 year of discharge and critical readmissions at any time after the Fontan operation are included in Tables 5 and 6, respectively. Post-operative length of stay of 14 days or longer was associated with emergency department utilisation within 1 year of discharge as was Fontan surgery at Site C. Warfarin was excluded from these analyses due to collinearity with centre (i.e., centre B prescribed it to all but one patient while it was not prescribed to any patients at centre C). Once removed, all variance inflation factors were less than 5, which is a conservative cut-point for indicating collinearity. From these analyses, we identified Fontan surgery at centre C to be independently associated with emergency department utilisation at any time point post-operatively (see Supplementary Table 2) but centre C was not associated with increased critical readmission. In contrast, surgery at centre B was not associated with emergency department utilisation within 1 year or overall but was independently associated with critical readmission. Independent of centre effect, post-operative length of stay of 14 days or longer was associated with emergency department utilisation within 1 year of discharge and critical readmission, while African-American/Black race was independently associated with critical readmission but not increased emergency department utilisation.

## Discussion

In a multi-centre cohort, almost half of the children with Fontan circulation utilised the emergency department. These patients most commonly presented with respiratory symptoms, and often with high disease acuity, as evidenced by high admission-to-emergency department visit ratio (36%). In contrast, the Agency for Healthcare Research and Quality reported that in 2015, 96.7% of paediatric emergency department visits were “treat-and-release”, with only 3.3% requiring hospital admission.<sup>10</sup> Hence, the rate of hospital admission for patients with Fontan circulation was 10 times that of the general paediatric population. Critical readmissions were also common, with approximately one in six patients with Fontan circulation required readmission to an ICU or direct transfer to the operating room or cardiac catheterisation suite for urgent intervention. In several cases, patients presented with life-threatening symptoms related to complications that are well known to be associated with Fontan circulation such as pleural effusions, atrial tachyarrhythmias, and plastic bronchitis.<sup>11</sup> Though many of these findings will not be surprising to specialists who routinely care for these children (e.g., paediatric cardiologists, cardiac intensivists), our results underscore the need for emergency department physicians and other front-line care providers to be aware of the unique nature of Fontan circulation and the propensity for these patients to necessitate urgent interventions and critical readmissions.

Patients with single ventricle anatomy, from the fragile physiology of the first inter-stage period to the unique physiology of the Fontan circulation, represent a very small fraction of the total patients that emergency department physicians encounter. Surveys of emergency department physicians have demonstrated that most emergency department physicians are uncomfortable with these patients, yet because of the low frequency of emergency department presentations relative to the general population, most paediatric and adult emergency department physicians deem education in single ventricle anatomy to be of low priority.<sup>1,12</sup> We assert that, despite the relative low occurrence rate of emergency department

**Table 3.** Bivariate comparison of characteristics of patients with and without ED visits within 1 year of discharge following their Fontan operation

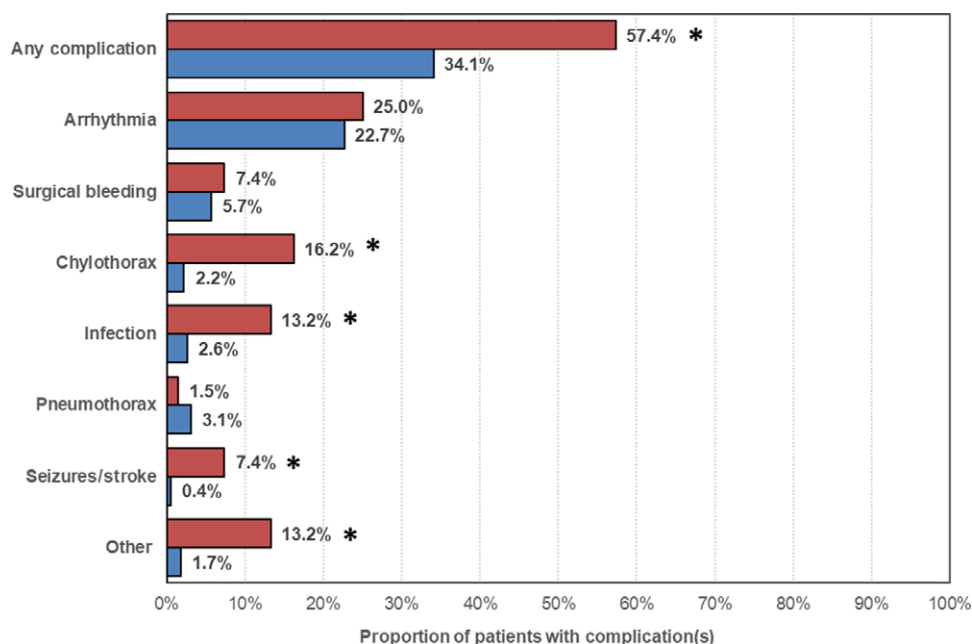
Patient characteristics	All patients (n = 297)	ED visit (n = 107)	No ED visits (n = 190)	p-Value
Age at surgery (years)	2.9 (2.2–3.6)	2.9 (2.2–3.8)	2.8 (2.2–3.5)	0.24
Weight (kg)	13.2 (11.9–15.0)	13.4 (11.6–15.2)	13.2 (11.9–14.8)	0.77
Female sex	127 (43%)	49 (46%)	78 (41%)	0.43
Race				0.009
Caucasian/White	181 (61%)	62 (58%)	119 (63%)	
African-American/Black	49 (16%)	25 (23%)	24 (13%)	
Hispanic/Latino ethnicity	8 (3%)	2 (2%)	6 (3%)	
Asian	9 (3%)	5 (5%)	4 (2%)	
Other	20 (7%)	9 (8%)	11 (6%)	
Unknown	30 (10%)	4 (4%)	26 (14%)	
Stage 1 Norwood	134 (45%)	49 (46%)	85 (45%)	0.86
> 3 cardiac surgeries	37 (12%)	14 (13%)	23 (12%)	0.81
Fontan type				0.57
Lateral tunnel	124 (42%)	47 (44%)	77 (41%)	
Extra-cardiac	173 (58%)	60 (56%)	113 (59%)	
Fenestration	270 (91%)	94 (88%)	176 (93%)	0.17
Additional procedure(s)	88 (30%)	38 (36%)	50 (26%)	0.10
CPB duration (minutes)	97 (77–124)	101 (80–136)	95.5 (75–121)	0.12
Post-operative complication	117 (39%)	49 (46%)	68 (36%)	0.09
Post-operative LOS (days)	9 (7–12)	10 (7–18)	9 (7–11)	0.01
Post-operative LOS $\geq$ 14 days	68 (23%)	34 (32%)	34 (18%)	0.006
Discharge medications				
ACE inhibitor	263 (89%)	99 (93%)	164 (86%)	0.10
Furosemide	272 (92%)	96 (90%)	176 (93%)	0.39
Spironolactone	234 (79%)	85 (79%)	149 (78%)	0.84
Chlorothiazide	141 (47%)	46 (43%)	95 (50%)	0.25
Three diuretic medications	119 (40%)	36 (34%)	83 (44%)	0.09
Aspirin	289 (97%)	102 (95%)	187 (98%)	0.11
Warfarin	216 (73%)	67 (63%)	149 (78%)	0.003

Continuous variables are represented as mean  $\pm$  standard deviation, median (25%, 75%) and categorical variables are represented as absolute counts (%). ACE = angiotensin converting enzyme; CPB = cardiopulmonary bypass; ED = emergency department; LOS = length of stay.

visitation, the high acuity at presentation and potential for life-threatening complications should motivate efforts to provide education on single ventricle anatomy and Fontan circulation aimed at emergency department physicians, nurses, and other medical staff. We do acknowledge, however, that while these efforts will likely be deemed useful to emergency department practitioners, they are unlikely to have an appreciable effect on reducing the frequency of emergency department visitation or acuity of presentation that we observed in our study.

We observed considerable variation in emergency department utilisation and critical readmissions across racial backgrounds. In particular, African-American/Black race was independently associated with critical readmission from the emergency department, such that odds of critical readmission for African-American/

Black patients were 2.5 times that of White/Caucasian. Racial disparities in healthcare have been described in the paediatric population.<sup>13–16</sup> A study by Gonzalez et al found that White children had lower mortality after congenital heart surgery compared to non-White patients.<sup>13</sup> Others have reported that children with Medicaid insurance had a higher risk of death than those with commercial or managed care.<sup>14</sup> Results from the Single Ventricle Reconstruction trial suggest that inter-stage mortality was associated with two sociodemographic variables: living in a census block with greater than 5% below the poverty level and Hispanic ethnicity.<sup>15</sup> Our findings suggest that a disparity in access to primary care or outpatient services may exist, such that African-American/Black children used the emergency department more frequently. Moreover, though speculative, the increased odds of critical



**Figure 2.** Proportion of postoperative complications in patients with prolonged postoperative hospitalization (red bar) compared to postoperative hospitalization < 14 days (blue bar).

readmission in African-American children could indicate that presentation of these children is more often delayed, leading to more life-threatening symptoms at the time of emergency department presentation.

We also observed an increased risk of emergency department utilisation and critical readmission in patients who experienced a prolonged post-operative course greater than or equal to 14 days following their Fontan operation. This finding is consistent with our previous work, where we have demonstrated that prolonged post-operative course greater than or equal to 14 days is also independently associated with emergency department utilisation during the first and second inter-stage periods in patients with single ventricle anatomy.<sup>1,5</sup> Further, the increased emergency department utilisation that was observed in patients with prolonged post-operative hospitalisations was most prevalent within the first year after the Fontan operation. Not surprisingly, these patients suffered post-operative complications more frequently than patients with shorter post-operative courses, and undoubtedly, many of these emergency department encounters that occurred within the first year were associated with these post-operative complications (e.g., arrhythmias, infections, and chylothoraces) and overall medical complexity. As time progressed, the effects of these complications likely diminished, but the risk of critical readmission remained. Prolonged post-operative course and associated complications are likely markers of overall disease complexity, and thus, not unexpectedly, are associated with increased need for emergency department utilisation and readmission after hospital discharge.

To address the relatively high proportion of patients with Fontan circulation utilising the emergency department or requiring critical readmission, cardiologists and other physicians who care for these patients could consider quality improvement initiatives with the intent of reducing the number of these encounters. Quality improvement initiatives targeting the subset of patients at risk for critical readmission may be feasible. Texter et al report their experience building a Single Ventricle Team from the framework of their existing infant home monitoring programme to encompass children after Stage II surgical palliation.<sup>17</sup> This team has reduced

inter-stage mortality and complications and with these successes and buy-in from key players, the group intends to extend monitoring through Fontan palliation.<sup>17-19</sup> Similarly, increased outpatient surveillance during the first year after hospital discharge for the subset of patients with prolonged length of stay after their Fontan operation would be justifiable. Centres should also examine their own local patterns of emergency department utilisation and hospital admissions for patients with Fontan circulation. For instance, the high ratio of emergency department encounters to critical readmissions observed at centre C, relative to the other two centres, suggests that some of the emergency department utilisation at this centre may be avoidable. Quality improvement initiatives focused on identifying the factors that contribute to this frequent emergency department utilisation that are specific to each individual centre are therefore warranted.

### Limitations

This study is limited by its retrospective design, which did not permit sample size calculations. We could only include emergency department visits and medical records that occurred within the health systems of the three participating institutions, which likely resulted in an underestimate of the overall emergency department use in this patient population. Likewise, we also did not classify patients who were admitted to a general ward or cardiology service and were transferred to an ICU or underwent a procedure afterwards as having critical readmissions, which likely resulted in an underestimate of the critical needs of these children after their Fontan operation. As the study consists of only three centres, generalisability may be limited. The study was also not designed to determine whether differences in centre-specific practices played a significant role in the observed differences in emergency department utilisation and critical admission. With only three centres involved, attempting to determine whether centre-specific practices such as warfarin usage, surgical approach to the Fontan circuit (i.e., lateral tunnel versus extra-cardiac), or other unmeasured site variations were responsible for the observed patterns of emergency

**Table 4.** Bivariate comparison of characteristics of patients with and without critical admissions from the ED at any time following their Fontan operation

Patient characteristics	All patients (n = 297)	Critical admit (n = 46)	No critical admit (n = 251)	p-Value
Age at surgery (years)	2.9 (2.2–3.6)	3.0 (2.1–3.7)	2.9 (2.2–3.5)	0.78
Weight (kg)	13.2 (11.9–15.0)	13.5 (12.0–15.0)	13.2 (11.8–14.8)	0.76
Female sex	127 (43%)	23 (50%)	104 (41%)	0.28
Race				0.09
Caucasian/White	181 (61%)	27 (59%)	154 (61%)	
African-American/Black	49 (16%)	13 (28%)	36 (14%)	
Hispanic/Latino ethnicity	8 (3%)	1 (2%)	7 (3%)	
Asian	9 (3%)	2 (4%)	7 (3%)	
Other	20 (7%)	2 (4%)	18 (7%)	
Unknown	30 (10%)	1 (2%)	29 (12%)	
Stage 1 Norwood	134 (45%)	24 (52%)	110 (44%)	0.30
> 3 cardiac surgeries	37 (12%)	5 (11%)	32 (13%)	0.72
Fontan type				0.008
Lateral tunnel	124 (42%)	11 (24%)	113 (45%)	
Extra-cardiac	173 (58%)	35 (76%)	138 (55%)	
Fenestration	270 (91%)	44 (96%)	226 (90%)	0.28
Additional procedure(s)	88 (30%)	21 (46%)	67 (27%)	0.01
CPB duration (minutes)	97 (77–124)	110 (84–138)	95 (76–122)	0.03
Post-operative complication	117 (39%)	24 (52%)	93 (37%)	0.05
Post-operative LOS (days)	9 (7–12)	11 (8–18)	9 (7–12)	0.001
Post-operative LOS $\geq$ 14 days	68 (23%)	18 (39%)	50 (20%)	0.004
Discharge medications				
ACE inhibitor	262 (89%)	42 (91%)	221 (88%)	0.62
Furosemide	272 (92%)	44 (96%)	228 (91%)	0.39
Spironolactone	234 (79%)	38 (83%)	196 (78%)	0.49
Chlorothiazide	141 (47%)	28 (61%)	113 (45%)	0.05
Three diuretic medications	119 (40%)	26 (57%)	93 (37%)	0.01
Aspirin	289 (97%)	41 (89%)	248 (99%)	0.003
Warfarin	216 (73%)	34 (74%)	182 (73%)	0.84
Duration of follow-up	43.9 (27.6–64.7)	44.4 (32.7–67.7)	43.9 (26.6–64.6)	0.39

Continuous variables are represented as mean  $\pm$  standard deviation, median (25%,75%) and categorical variables are represented as absolute counts (%)  
 ACE = angiotensin converting enzyme; CPB = cardiopulmonary bypass; ED = emergency department; LOS = length of stay

department utilisation or critical readmission is not possible. Accordingly, we cannot comment on the possible benefits or detriments of the use of warfarin prophylaxis against thrombotic complications, which was the dominant practice at two of the three centres but not utilised in any patients in the third centre (and thromboembolic events only occurred in two patients), nor can we comment on whether the lateral tunnel or extra-cardiac approach to the Fontan operation influenced our findings. We further acknowledge that there are likely other intangible or non-measurable factors that contributed to the rate of emergency department utilisation and critical readmission across centres including access to care, geographic factors, and socioeconomic factors that were not measured. Lastly, we purposefully did not

elaborate upon the significant relationship noted in Tables 5 and 6 between patients for which race was not specified and decreased emergency department utilisation and critical admissions, as the absence of race or ethnicity data in the patients makes these findings uninterpretable.

### Conclusion

In this study, nearly half of patients with Fontan circulation received emergency department care, often presenting with high disease acuity requiring critical readmission. Emergency department utilisation and need for critical readmission were significantly influenced by the centre at which surgery was performed,

**Table 5.** Multi-variable analysis of risk factors for emergency department utilisation within 1 year of discharge after Fontan palliation

Variables	Odds ratio (95% confidence interval)	p-Value
Centre*		
B	1.4 (0.7, 2.5)	0.32
C	2.4 (1.2, 4.8)	0.02
Race**		
African-American/Black	1.6 (0.8, 3.1)	0.19
Other	1.1 (0.5, 2.4)	0.78
Unknown	0.3 (0.1, 1.0)	0.04
Post-operative length of stay $\geq$ 14 days	1.9 (1.1, 3.4)	0.03

\*Reference variable: centre A (default)

\*\* Reference variable: Caucasian/White race (most frequent)

**Table 6.** Multi-variable analysis of risk factors for critical admission at any time following the Fontan operation

Variables	Odds ratio (95% confidence interval)	p-Value
Centre*		
B	6.1 (2.3, 16.3)	<0.001
C	2.3 (0.7, 7.0)	0.15
Race**		
African-American/Black	2.5 (1.0, 6.0)	0.04
Other	0.7 (0.2, 2.2)	0.60
Unknown	0.1 (0.0, 1.0)	0.05
Post-operative length of stay $\geq$ 14 days	3.3 (1.5, 6.9)	0.002

\*Reference variable: centre A (default)

\*\* Reference variable: Caucasian/White race (most frequent)

racial background, and the duration of post-operative hospitalisation. Patients with Fontan circulation at high risk for emergency department utilisation and critical readmission, namely African-American/Black patients and patients with post-operative length of stay of 14 days or more after their Fontan operation, should be considered targets for quality improvement initiatives aimed at reducing morbidity in this patient population.

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2008, and has been approved by the institutional committees of Wayne State University, University of Indiana, and University of Wisconsin.

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