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Association of post-operative ICU requirements with early extubation in the fontan procedure

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Abstract

Objectives: This study investigated the association between early extubation (EE) and the degree of postoperative intensive care unit (ICU) support after the Fontan procedure, specifically evaluating the volume of postoperative intravenous fluid (IVF) and vasoactive-inotropic score (VIS). *Methods:* Retrospective analysis of patients who underwent Fontan palliation from 2008 to 2018 at a single center was completed. Patients were initially divided into pre-institutional initiative towards EE (control) and post-initiative (modern) cohorts. Differences between the cohorts were assessed using t-test, Wilcoxon, or chi-Square. Following stratification by early or late extubation, four groups were compared via ANOVA or Kruskal-Wallis Test. *Results:* There was a significant difference in the rate of EE between the control and modern cohorts (mean 42.6 versus 75.7%, $p = 0.01$). The modern cohort demonstrated lower median VIS (5 versus 8, $p = 0.002$), but higher total mean IVF (101±42 versus 82 ±27 cc/kg, $p < 0.001$) versus control cohort. Late extubated (LE) patients in the modern cohort had the highest VIS and IVF requirements. This group received 67% more IVF (140 ± 53 versus 84 ± 26 cc/kg, $p < 0.001$) and had a higher median VIS at 24 hours (10 (IQR, 5–10) versus 4 (IQR, 2–7), $p < 0.001$) versus all other groups. In comparison, all EE patients had a 5-point lower median VIS when compared to LE patients (3 versus 8, $p= 0.001$). *Conclusions:* EE following the Fontan procedure is associated with reduced post-operative VIS. LE patients in the modern cohort received more IVF, potentially identifying a high-risk subgroup of Fontan patients deserving of further investigation.

The third stage of single-ventricle palliation, the Fontan procedure, creates a single series circuit inclusive of systemic and pulmonary circulations. In this circuit, pulmonary blood flow relies on passive flow from the systemic venous system. The addition of positive pressure ventilation to this passive intrathoracic system would decrease both pulmonary blood flow and cardiac output. Therefore, early extubation (EE) in post-operative Fontan patients has been theoretically evaluated and employed in clinical practice to improve post-operative hemodynamics.

Despite this understanding of Fontan physiology, clinical post-operative ventilatory management of this patient population remains varied, possibly due to a lack of supportive evidence that EE improves clinical outcomes. The literature has shown improved hemodynamic performance by means of reduced mean pulmonary artery pressure and increased cardiac index.[1] Following these findings, further investigations have shown that extubation is feasible and safe, but the literature remains both limited and varied regarding the clinical impact of EE in the Fontan patient.[2–9] Specifically, there is very little evidence that EE decreases postoperative intensive care unit (ICU) needs.

This study was conducted to determine the association between EE after the Fontan procedure with postoperative ICU needs, using the primary clinical outcomes of volume of post-operative intravenous fluid (IVF) administration and vasoactive-inotropic support. Length of ICU and hospital stay was evaluated in this study but not considered a primary outcome due varied hospital practices.

Materials and methods

Study population

A retrospective chart review was performed for all patients < 18 years old who underwent a Fontan procedure between January 2008 and December 2018 at NewYork-Presbyterian Morgan Stanley Children's Hospital, Columbia University Irving Medical Center (IRB approval 9/6/2016, IRB-AAAS0380). Patients with preoperative need for invasive and/or positive pressure

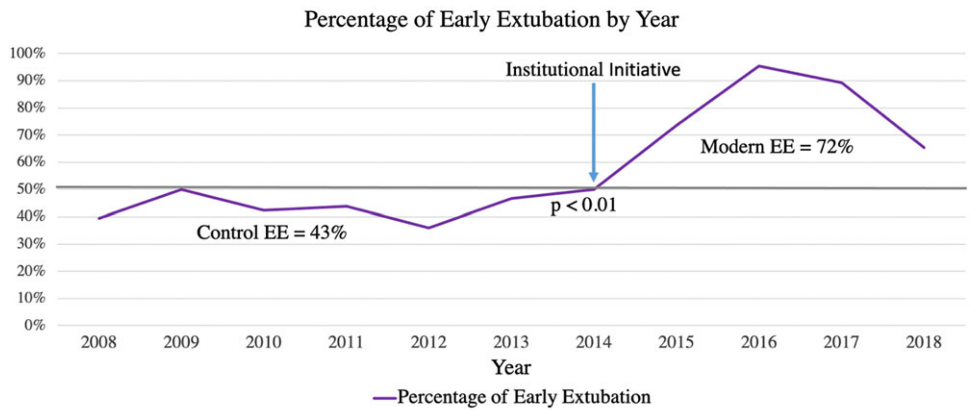

Figure 1. Percentage of early extubation (EE) by year. Time of institutional initiative demarcated, with significant change in rate of EE in the modern cohort.

ventilation, single-lung physiology, and inaccessible medical records were excluded. A comprehensive review of the medical records related to pre- and post-operative patient characteristics and clinical parameters was performed on each patient.

Operative and perioperative management

All patients underwent preoperative transthoracic echocardiography and almost all underwent pre-Fontan cardiac catheterization. Pre-operative hemodynamics were collected from cardiac catheterizations occurring from up to one year prior to operative date. In certain cases (i.e. multiple sources of pulmonary blood flow), PVRI could not be accurately calculated and therefore not included. In rare cases, catheterization data were not available and/or catheterization date was greater than 1 year from operative date. In these cases, the remainder of patient data were analyzed with catheterization data omitted from analysis. All patients were managed post-operatively in the pediatric cardiac ICU.

Postoperative management and outcome variables

In 2014, there was a clinical initiative towards EE at our institution. Patients were thus divided into two groups: those who underwent their Fontan procedure between January 1, 2008 and December 31, 2013 (control cohort) and those who underwent Fontan procedure between January 1, 2014 and December 31, 2018 (modern cohort). In order to assess the accuracy of the pre-defined cut off, the percent of EE patients by year was calculated. There was a significant difference in the rate of EE from 2008–2013 compared to 2014–2018 (mean 42.6 versus 75.7%, $p = 0.01$) (Fig. 1). For additional analyses, these era-based cohorts were stratified by timing of extubation, creating a total of 4 study groups: control EE, control LE, modern EE, and modern LE.

The primary predictor of interest was the above described clinical practice change towards EE in the postoperative Fontan patient, defined as extubation in the operating room or within 6 hours of admission to the ICU. Late extubation (LE) was defined as extubation later than 6 hours from ICU admission.

The primary outcomes of interest were volume of postoperative IVF administration and vasoactive-inotropic support. Postoperative IVF administration (crystalloid solution, cc/kg) was divided into 6 hours periods of the first 24 hours following ICU admission. All drips, maintenance IVF, and IVF boluses were included in the volume. Boluses versus maintenance fluids were not separated due to limitations in electronic medical record and need to capture total IVF given. Cardiovascular support was defined using the vasoactive-inotropic score (VIS)[10–12] collected at 6-hour time intervals for the first 24 hours following ICU admission. Hospital mortality and rate of reintubation are reported in descriptive statistics only as the expected and observed incidence was too low to anticipate meaningful associations. The secondary outcomes were ICU length of stay (LOS), defined as number of postoperative days at time of transfer to cardiac floor, as well as overall hospital LOS.

Other outcomes included systolic and diastolic blood pressure along with central venous pressure collected at 6-hour intervals in the first 24-hour post-operative period. Hemoglobin and arterial blood gas analyses were collected at 6-hour intervals in the first 24-hour postoperative period. As times of blood samples varied, results from within 1 hour of the 0- and 6-hour postoperative time mark, within 2 hours of the 12- and 18-hour time mark, and within 4 hours of 24-hour time mark were collected.

Statistical methods

Clinical and demographic variables were described using standard summary statistics, including number and frequency for categorical variables, mean values with standard deviations for continuous variables with normal distribution, and median values with interquartile ranges when data were not normally distributed. Comparisons between the two cohorts (control and modern era) were made using Students *t*-test, Wilcoxon or chi-Square as appropriate for data type. After stratifying patients by timing of extubation (EE versus LE), the four resultant groups were compared by ANOVA when variables were normally distributed and Kruskal-Wallis Test in the case of unequal variance. No further subgroup post-hoc analyses were performed. P values < 0.05 were considered to be statistically significant. All analyses were performed using Stata software, version 13.1 (StataCorp, College Station, Texas).

IRB approval

This study was approved by the Columbia University Medical Center Institutional Review Board, with waiver of informed consent.

Results

Patient characteristics and operative data:

Patient characteristics of the 265 patients included in the study are reported in Tables 1 and 2. Comparison between control and modern cohorts demonstrated similar baseline patient

Table 1. Patient characteristics comparing control versus modern era fontan patients.

	Control (n = 150)	Modern (n = 115)	p
Sex, male (%)	88 (59)	71 (62)	0.61
Age, months (IQR)	42 (29–50)	45 (38–54)	0.01
Weight, kg (IQR)	13.8 (12.2–15.9)	14.6 (13.2–16.9)	0.04
Race, n (%)			0.59
White/Hispanic	98 (65)	71 (62)	
Black	22 (15)	21 (18)	
Asian	2 (1)	4 (3)	
Other	27 (18)	19 (17)	
Ventricular Dominance, n (%)			0.39
Right Ventricle	96 (64)	66 (57)	
Left Ventricle	50 (33)	43 (37)	
Other	4 (3)	6 (5)	
Diagnosis, n (%)			0.39
Hypoplastic left heart	70 (47)	51 (44)	
Tricuspid atresia	20 (13)	18 (16)	
Atrioventricular septal defect	15 (10)	11 (10)	
Double outlet right ventricle	18 (12)	8 (7)	
Double inlet left ventricle	11(7)	17 (15)	
Pulmonary atresia/intact ventricular septum	6 (4)	4 (3)	
Transposition of the great arteries	5 (3)	1 (1)	
Other	5 (3)	5 (4)	
Pre-Surgical Catheterization Data (IQR)			
SVC SpO_2, %	67 ± 6	66 ± 7	0.46
Aorta SpO_2, %	86 (83–89)	85 (82–88)	0.12
SVC mean pressure, mmHg	12 (10–13)	11 (9–13)	0.96
PVRi, woods unit x m^2/kg	1.5 (1.2–2)	1.4 (1.1–2.1)	0.47
Cardiac index, L/min/m^2	4.3 (3.6–5)	3.5 (2.9–4.3)	<0.01

Numbers represent mean/medians (SD/IQR) for continuous variables and numbers (%) for categorical variables.
SVC = superior vena cava; PVRi = pulmonary vascular resistance indexed; SpO2 = oxygen saturation.

characteristics (Table 1). Significant differences included patients in the modern cohort being slightly older, having higher preoperative weight, and lower pre-operative cardiac index. With stratification of these groups by timing of extubation, the characteristics among groups remained similar (Table 2). Cardiac catheterization data were also similar among all groups, with the exception of cardiac index which was significantly lower in both the EE and LE groups of the modern cohort. Mean SVC pressure was also significantly higher in the modern LE group.

Comparisons of operative data between cohorts are shown in Tables 3 and 4. The modern cohort had a significantly smaller number of patients requiring circulatory arrest (CA) and those who did require CA had significantly shorter times in the modern cohort (Table 5). The modern cohort also had a significantly higher incidence of Fontan fenestration as well as extracardiac conduits performed (Table 5). Analysis of both cohorts stratified by EE and LE (Table 4) demonstrated that late extubated patients in both the control and modern cohorts had significantly longer cardiopulmonary bypass (CPB) times when compared to EE patients. The length of aortic cross-clamp was significantly lower in the patients who underwent EE in the modern cohort compared to all other groups.

Primary outcomes

The modern cohort demonstrated lower median VIS at all individual time points when compared to the control cohort (Fig. 2). When VIS was averaged over the 24-hour period, the modern group demonstrated a lower median VIS than the control group (5 versus 8, $p = 0.002$).

When stratified by EE and LE (Fig. 3), there was a significant difference between VIS of all groups, with the control LE cohort having the highest VIS for the first 12 hours. After 12 hours, this group's VIS decreased while the VIS for the modern LE cohort remained high. At 24 hours postoperatively, the modern LE cohort had the highest VIS with a median 6-point higher VIS when

Table 2. Patient characteristics comparing control versus stratified by early and late extubation.

	Control, EE (n = 65)	Control, LE (n = 85)	Modern, EE (n = 87)	Modern, LE (n = 28)	p
Sex, male (%)	48 (57)	40 (62)	20 (71)	51 (59)	0.55
Age, months (IQR)	42 (26–103)	40 (33–48)	45 (39–45)	45 (39–55)	0.05
Weight, kg (IQR)	14. (12.4–15.9)	13.7 (12–15.3)	14.6 (12.8–16.1)	15 (13.3–17.4)	0.08
Race, n (%)					0.47
White/Hispanic	18 (21)	9 (14)	15 (17)	4 (14)	
Black	52 (61)	46 (71)	50 (58)	21 (75)	
Asian	14 (17)	8 (12)	19 (22)	2 (7)	
Other	1 (1)	2 (3)	3 (3)	1 (4)	
Ventricular dominance, n (%)					0.25
Right Ventricle	61 (72)	35 (54)	18 (64)	48 (55)	
Left Ventricle	22 (26)	28 (43)	9 (32)	34 (39)	
Other	2 (2)	2 (3)	1 (4)	5 (6)	
Diagnosis, n (%)					0.51
Hypoplastic left heart	27 (42)	43 (52)	37 (43)	14 (50)	
Tricuspid atresia	9 (14)	11 (13)	12 (14)	6 (21)	
Atrioventricular septal defect	6 (9)	9 (11)	8 (9)	3 (11)	
Double outlet right ventricle	8 (12)	10 (12)	5 (6)	3 (11)	
Double inlet left ventricle	8 (12)	3 (4)	16 (18)	1 (4)	
Pulmonary atresia/intact ventricular septum	3 (5)	3 (4)	4 (5)	0 (0)	
Transposition of the great arteries	3 (5)	2 (2)	1 (1)	0 (0)	
Other	1 (2)	4 5)	4 (5)	1 (4)	
Pre-surgical catheterization data (SD)					
SVC SpO_2, %	68 ± 6	66 ± 6	66 ± 7	68 ± 5	0.39
Aorta SpO_2, %	87 ± 5	85 ± 5	84 ± 5	83 ± 15	0.12
SVC mean pressure, mmHg	11 ± 3	12 ± 3	11 ± 15	14 ± 5	0.02
PVRI, woods unit x m^2/kg	1.5 ± 0.7	1.9 ± 1.2	1.8 ± 1.4	1.8 ± 0.8	0.23
Cardiac index, L/min/m^2	4.6 ± 1.3	4.5 ± 1.4	3.7 ± 1.2	3.7 ± 1.3	<0.01

Numbers represent mean/medians (SD/IQR) for continuous variables and numbers (%) for categorical variables.
SVC = superior vena cava; PVRI = pulmonary vascular resistance indexed; SpO2 = oxygen saturation.

compared to the other 3 groups combined (10 (IQR, 5–16) versus 4 (IQR, 2–7), $p < 0.001$).

In the analysis of IVF, the modern cohort demonstrated a higher volume of IVF resuscitation than the control cohort (Fig. 4). Cumulatively over the 24-hour period, the modern cohort demonstrated higher mean total IVF resuscitation when compared to the control cohort. (101 ± 27 versus 82 ± 42 cc/kg, $p < 0.001$).

When control and modern cohorts were stratified by EE and LE (Fig. 5), the modern LE cohort received significantly more IVF at each time mark. When averaged over the 24 hour period, this group received 67% more total IVF resuscitation (140 ± 53 versus 84 ± 26 cc/kg, $p < 0.001$).

Secondary outcomes

Further supporting the finding of increased IVF resuscitation and VIS, modern LE cohort had the lowest mean systolic blood pressure as well as highest mean peak lactate and largest base deficit (Table 5). There was no significant difference in median ICU or hospital LOS between control and modern cohorts on initial analysis. When these groups were stratified into EE versus LE, EE patients did have a significantly shorter ICU and overall hospital LOS. The rate of reintubation across all groups was not different (Table 5).

Discussion

As there is currently limited literature demonstrating the clinical impact of EE following the Fontan procedure, our study aimed to add to the evidence for EE by investigating the association between early extubation and degree of postoperative ICU support, specifically by postoperative IVF resuscitation and VIS. It is recognized that many institutions have adopted the practice of EE following the Fontan procedure by the time of this publication, however the literature and proven clinical impact of this practice remain lacking. The outcomes of IVF resuscitation and VIS were chosen as they serve as a proxy for ICU utilization and acuity of the postoperative patient. There are also known morbidities associated with these two factors, including but not limited to pleural

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Table 3. Operative characteristics comparing control versus modern era fontan patients.

	Control (n = 150)	Modern (n = 115)	p
CPB, min (SD)	114 ± 49	107 ± 45	0.2
Cross-clamp, min (IQR)	41 (8-58)	0 (0-63)	0.05
Underwent circulatory arrest, n (%)	40 (27)	8 (7)	<0.01
If underwent circulatory arrest, min (SD)	31 ± 13	14 ± 10	<0.01
Fontan Fenestration, n (%)	63 (42)	71 (62)	<0.01
Extracardiac Fontan, n (%)	80 (53)	109 (95)	<0.01
Concomitant procedures, n (%)			0.14
None	114 (76)	75 (65)	
PA Reconstruction	17 (11)	21 (18)	
Atrioventricular valve repair	4 (3)	5(4)	
Arch reconstruction	2 (1)	1 (1)	
Atrial septectomy	3 (2)	0 (0)	
Innominate vein repair	1 (1)	0 (0)	
Aortic valve repair	1 (1)	0 (0)	
Pulmonary vein repair	1 (1)	6 (5)	
Pacemaker placement	0 (0)	1 (1)	
Multiple procedures	7 (5)	6 (5)	

Numbers represent mean/medians (SD/IQR) for continuous variables and numbers (%) for categorical variables.
CPB = cardiopulmonary bypass; PA = pulmonary artery.

effusions, duration of post-operative chest tubes, infection, and lack of mobility due to invasive monitoring.

We found that EE following the Fontan procedure reduced postoperative VIS while also identifying a high-risk subgroup of Fontan patients. As the decision for EE depends on multiple and often complex patient and clinical characteristics, we used an institutional initiative towards EE to aid in creating control and study (modern) cohorts. As expected, the modern cohort had a significantly higher rate of EE, but patient characteristics remained similar, thus allowing us to investigate the effects of EE.

The original analysis found that the modern cohort had significantly reduced VIS in the first postoperative 24 hours, which was consistent with our hypothesis that EE results in reduced ICU requirements. However, this same group was also found to have significantly higher postoperative IVF resuscitation. Given this interesting finding, further exploration was warranted. While it was possible that practice changes over time resulted in more aggressive fluid resuscitation in lieu of vasoactive medications, there were possibly other reasons. To delve into this question, the population was further stratified and analyzed into groups based on EE versus LE. On stratified analysis, it was discovered that the LE patients in the modern cohort were outliers with significantly higher volume of IVF resuscitation and VIS than all other groups, and this subgroup accounted for the differences between the time-based cohorts. This was further highlighted by the observation that the volume of fluid administration and VIS in the control EE and modern EE were very similar. This implies that there was not a practice change in strategy of fluid administration, but instead the patients themselves. Furthermore, this group was found to have the lowest systolic blood pressures, highest peak lactate, and largest base deficit when compared to the other three groups. There were other postoperative hemodynamic and blood gas analyses that met statistical significance, but were not felt to be clinically impactful (i.e., small differences in diastolic blood pressure, central venous pressure, minimum pH, peak PaCO2, minimum PaO2).

The findings of significantly higher VIS and IVF resuscitation requirements in the modern LE cohort identifies a specific population of patients that warrants further investigation. Factors commonly used to risk-stratify Fontan patients such as ventricular dominance and PVRI were similar among all of the groups. Atrioventricular valve regurgitation could be considered but was not included in this investigation. The modern cohort overall had a lower cardiac index, but cardiac index was the same in both EE and LE modern cohorts. Notably, the modern LE cohort did have the highest mean SVC pressure. Thus the combination of lower cardiac index with higher mean SVC pressure in the modern LE group could have been noted pre-operatively and resulted in the higher rate of fenestrations in the group. However, this group still required the most ICU support. The presence of a fenestration in this higher risk group does not appear to mitigate all post-operative risk for hemodynamic decompensation and thus further investigation is warranted to identify pre-operative factors which may predict post-operative decompensation.

When considering pre-operative characteristics, the modern cohort was noted to have significantly lower preoperative cardiac index. This is likely attributed to new surgical techniques and preferences, along with an increasing willingness to perform the Fontan procedure in higher risk and/or more complex patients. There were also differences in utilization and length of CA along with significantly higher incidence of Fontan fenestration and use of extracardiac conduit in the modern cohort. Once again, this is likely due to advancements in surgical techniques as well as specific surgeons' preferences. When the cohorts were separated by EE versus LE, the previous findings regarding CA remained the same, but LE patients in both the modern and control cohort also had significantly longer CPB times when compared to EE patients. The length of aortic cross-clamp was also significantly lower in the modern EE cohort when compared to all other groups. All of these findings help to illustrate that surgical characteristics play an important part in the complex decision of anesthesiologists and intensivists regarding EE. Lower CA, aortic cross-clamp, and CPB times likely influenced the provider's decision towards EE in the modern cohort. Similarly, patients with longer operative courses are likely to be viewed as sicker patients and therefore more likely to be kept intubated.

When comparing the modern versus control cohorts, there was not a significant different in ICU LOS. When these groups were stratified, the ICU and hospital LOS was significantly shorter in both the modern and control EE groups (Table 5).

This study is limited by its retrospective observational nature at a single institution, demonstrating associations between EE and reduced ICU requirements. Given its retrospective nature, we cannot establish a causal relationship between EE and improved clinical outcomes. Ideally multi-institutional prospective trials would be performed to further investigate and confirm these associations.

Also, as the data were collected over a 10-year period, clinical and operative practices are subject to change. Specifically, there were changes in surgeons as well as technical aspects of the Fontan procedure, including presence of fenestrations, need for concomitant procedures, and utilization of aortic cross clamp. During this time period, there were also undoubtedly changes in the

Table 4. Operative characteristics comparing control versus modern era stratified by early and late extubation.

	Control, EE (n = 65)	Control, LE (n = 85)	Modern, EE (n = 87)	Modern, LE (n = 28)	p
CPB, min (SD)	101 ± 41	131 ± 51	108 ± 41	122 ± 58	<0.01
Cross-clamp, min (IQR)	30 (0–48)	43 (19–70)	0 (0–63)	33 (0–65)	<0.01
Underwent Circulatory arrest, n (%)	17 (26)	23 (27)	3 (4)	5 (18)	<0.01
If underwent circulatory arrest, min (SD)	25 ± 7	35 ± 15	12 ± 9	16 ± 12	0.03
Fontan Fenestration, n (%)	27 (42)	36 (42)	51 (59)	20 (71)	<0.01
Extracardiac Fontan, n (%)	34 (52)	46 (54)	82 (94)	27 (96)	<0.01
Concomitant procedures, n (%)					0.12
None	61 (94)	53(62)	62 (71)	13 (46)	
PA Reconstruction	0 (0)	17 (20)	16 (18)	5 (18)	
Atrioventricular valve repair	2 (3)	2(2)	3 (3)	2 (7)	
Arch reconstruction	0 (0)	2(2)	0 (0)	1 (4)	
Atrial septectomy	0 (0)	3 (4)	0 (0)	0 (0)	
Innominate vein repair	0 (0)	1 (1)	0 (0)	0 (0)	
Aortic valve repair	0 (0)	1 (1)	0 (0)	0 (0)	
Pulmonary vein repair	1 (2)	0 (0)	2 (2)	4 (14)	
Pacemaker placement	0 (0)	0 (0)	0 (0)	1 (4)	
Multiple procedures	1 (2)	6 (7)	3 (5)	2 (7)	

Numbers represent mean/medians (SD/IQR) for continuous variables and numbers (%) for categorical variables.
CPB = cardiopulmonary bypass; PA = pulmonary artery.

Table 5. Post-operative data of control versus modern era stratified by early and late extubation.

	Control, EE (n = 65)	Control, LE (n = 85)	Modern, EE (n = 87)	Modern, LE (n = 28)	p
Reintubation, n (%)	2 (3)	3 (4)	3 (4)	4 (14)	0.08
Length of Stay					
Intensive care unit, days (IQR)	3 (2–4)	5 (4–7)	4 (2–7)	8 (4–16)	<0.01
Hospital, days (IQR)	9 (1–12)	11 (8–15)	9 (8–13)	12 (10–25)	<0.01
Hemodynamics					
Systolic blood pressure, mmHg (SD)	96 ± 14	88 ± 12	96 ± 9	82 ± 11	<0.01
Diastolic blood pressure, mmHg (SD)	56 ± 9	52 ± 6	58 ± 6	54 ± 6	<0.01
Central Venous Pressure, mmHg (SD)	15 ± 4	16 ± 3	17 ± 3	18 ± 4	<0.01
Blood gas analyses					
Minimum pH (SD)	7.30 ± 0.06	7.29 ± 0.06	7.27 ± 0.01	7.24 ± 0.07	<0.01
Peak PaCO2, mmHg (IQR)	45 (41–51)	46 (44–52)	47 (43–54)	50 (46–55)	0.02
Minimum PaO2, mmHg (SD)	66 ± 18	65 ± 17	69 ± 20	62 ± 19	0.02
Peak lactate, mmol/L (SD)	3.8. (3.1–4.6)	4.2 (3.6–5.5)	3.2 (2.4–4.2)	4.3 (3.1–5.2)	<0.01
Largest base deficit, mEq/L (IQR)	−5.8 (2.7)	−5.8 (3.0)	−6.3 (2.4)	−7.9 (2.7)	0.01

Numbers represent mean/medians (SD/IQR) for continuous variables and numbers (%) for categorical variables.
PaCO2 = partial pressure of carbon dioxide; PaO2 = partial pressure of oxygen.

anesthesiology and ICU care team along with IVF and inotropic preferences. These factors all have an impact on post-operative hemodynamics and the decision for early extubation. Although these differences are present in our patients and comparison would be more straightforward to limit analysis to isolated Fontan operations with single management team, this would not be an accurate representation of the patient population or hospital environment, while also excluding an important, potentially higher-risk group of patients. Other pre-operative parameters that were not included in this analysis but would be helpful in

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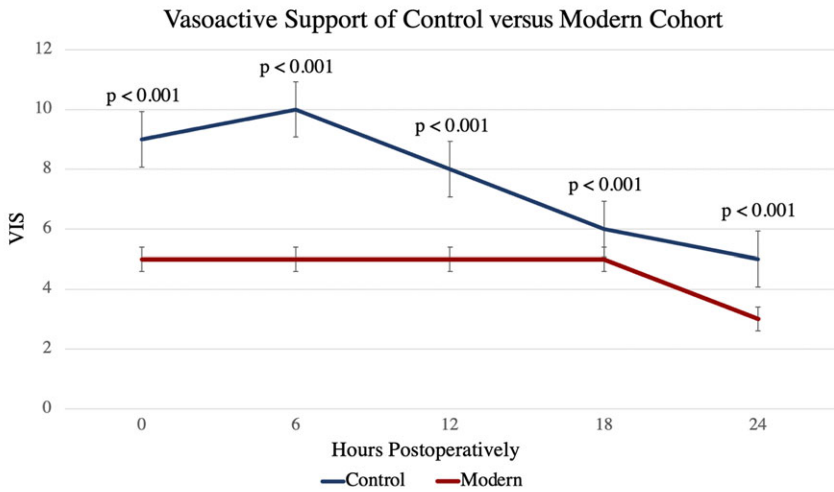

Figure 2. Median VIS in the first 24 postoperative in control versus modern cohort. Median vasoactive-inotropic score (VIS) in the first 24 postoperative in control versus modern cohort.

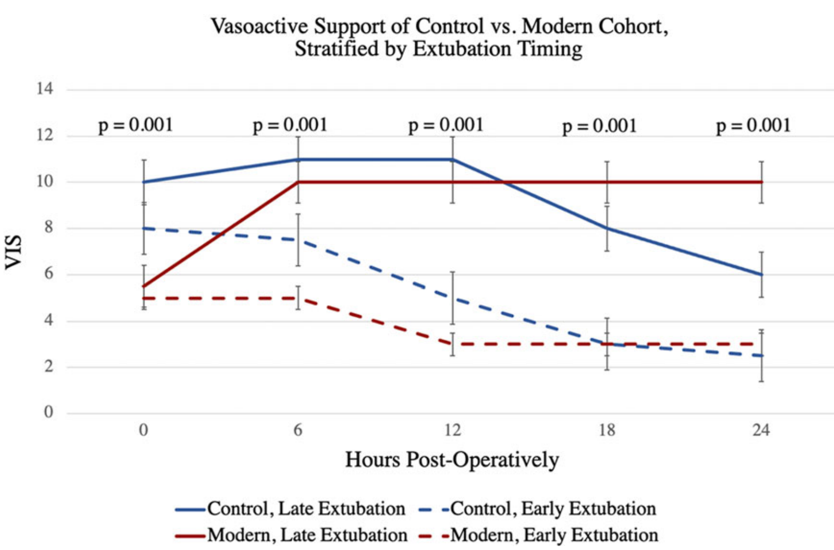

Figure 3. VIS (vasoactive-ionotropic score) stratified by cohort and timing of extubation.

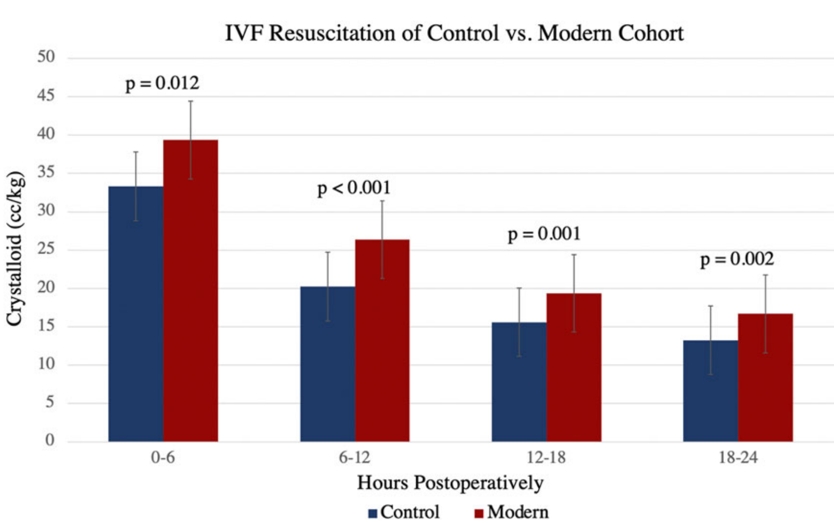

Figure 4. Mean volume of IVF (intravenous fluid) resuscitation in the first 24 postoperative divided by 6-hour intervals in control versus modern cohort.

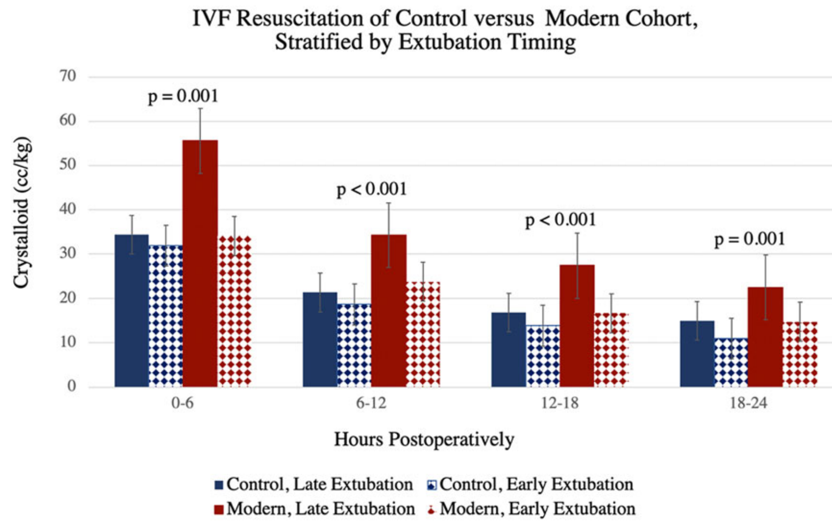

Figure 5. IVF (intravenous fluid) resuscitation stratified by cohort and timing of extubation.

future investigations include degree of atrioventricular valve regurgitation and collateral burden.

Finally, we recognize that clinical bias is a factor to consider in this analysis. When the expectation is that a Fontan will be extubated in the OR or shortly thereafter, there is an inherent bias towards the patients that are not extubated. Providers may be more cautious as they have already been labeled as a "sick" patient and thus be more proactive with increased IVF resuscitation and inotropic support. This bias is somewhat founded in the fact that patients in the modern cohort had lower preoperative cardiac index when compared to the control cohort, however cardiac index was similar in both EE and LE patients. This indicates that in the modern cohort, there may be a trend to operate on "sicker" patients in general. Thus, this study's findings of significantly increased IVF resuscitation and VIS in the late extubated patients of the modern cohort, highlights that this population requires more investigation as surgical management of cardiac lesions has become more aggressive over time.

Conclusions

Early extubation following the Fontan is associated with reduced ICU requirements, specifically lower VIS. A more contemporary subset of patients who were extubated late required more IVF resuscitation and had higher VIS at 24 hours postoperatively. Thus, this specific population warrants further investigation to identify reasons for higher postoperative ICU needs in order to improve clinical practices.

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