THE USE OF PULMONARY DEAD SPACE FRACTION TO IDENTIFY RISK OF PROLONGED
MECHANICAL VENTILATION IN CHILDREN AFTER CARDIAC SURGERY

A thesis submitted to the University of Arizona College of Medicine – Phoenix
in partial fulfillment of the requirements for the Degree of Doctor of Medicine

Muniza Siddiqui
Class of 2017

Mentor: Brigham Willis, MD
Acknowledgements

A special recognition to Dr. Renee Devor and Paul Kang, who provided immense time, insight, and assistance with this project.
Abstract

Background and Significance: Children with prolonged mechanical ventilation after cardiac surgery have a higher risk for poor outcome due to a variety of ventilator-associated morbidities. It therefore becomes essential to identify these children at higher risk of prolonged mechanical ventilation as well as find methods to identify children ready to be extubated as early as possible to avoid these complications. One physiological variable, the pulmonary dead space fraction ($V_D/V_T$), has been suggested as a possible indicator of prolonged mechanical ventilation. $V_D/V_T$ essentially measures the amount of ventilated air that is unable to participate in gas exchange.

Research Question: Can $V_D/V_T$ be used successfully in children undergoing cardiac surgery to identify those at risk for prolonged mechanical ventilation and identify those ready for extubation?

Methods: Retrospective chart review of 461 patients at Phoenix Children’s Hospital in the Pediatric Cardiac Intensive Care Unit since the initiation of standard application of the Philips NM3 monitors in October 2013 through December 2014. From the 461 patients screened, only 99 patients met all the inclusion criteria. These 99 patients consisted of 29 patients with balanced single ventricle physiology and 61 patients with two ventricle physiology.

Results: Initial postoperative and pre-extubation $V_D/V_T$ values correlated with length of mechanical ventilation for patients with two ventricle physiology but not for patients with single ventricle physiology. Additionally, pre-extubation $V_D/V_T$ values of greater than 0.5 indicated higher rates of extubation failure in two ventricle patients.

Conclusion: For children with two ventricle physiology undergoing cardiac surgery, $V_D/V_T$ should be used clinically to estimate the length of mechanical ventilation for these children. $V_D/V_T$ should also be checked in these patients before attempting to extubate. If $V_D/V_T$ is found to be
higher than 0.5, extubation should not be attempted since the patient is at a much higher risk for extubation failure.
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction/Significance</td>
<td>1 – 3</td>
</tr>
<tr>
<td>Materials and Methods</td>
<td>4 – 6</td>
</tr>
<tr>
<td>Results</td>
<td>7 – 17</td>
</tr>
<tr>
<td>• Pulmonary Dead Space Fraction</td>
<td>7 – 8</td>
</tr>
<tr>
<td>• Dynamic Pulmonary Compliance</td>
<td>9 – 10</td>
</tr>
<tr>
<td>• Airway Resistance</td>
<td>11 – 12</td>
</tr>
<tr>
<td>• Extubation Failure</td>
<td>13 – 14</td>
</tr>
<tr>
<td>• Length of Mechanical Ventilation</td>
<td>15 – 17</td>
</tr>
<tr>
<td>Discussion</td>
<td>18 – 19</td>
</tr>
<tr>
<td>Limitations</td>
<td>20</td>
</tr>
<tr>
<td>Future Directions</td>
<td>21</td>
</tr>
<tr>
<td>Conclusions</td>
<td>22</td>
</tr>
<tr>
<td>References</td>
<td>23 – 24</td>
</tr>
</tbody>
</table>
List of Figures and Tables

Figures

- Figure 1 - Page 6: Flow chart for selection, inclusion, and exclusion of patients
- Figure 2 - Page 8: Natural Progression of Dead Space Fraction. Median with 95% Confidence interval for each time interval. P-trend calculated using the Linear Mixed Effects Model.
- Figure 3 - Page 10: Natural Progression of Dynamic Pulmonary Compliance. Median with 95% Confidence interval for each time interval. P-trend calculated using the Linear Mixed Effects Model.
- Figure 4 - Page 12: Natural Progression of Airway Resistance. Median with 95% Confidence interval for each time interval. P-trend calculated using the Linear Mixed Effects Model.
- Figure 5 - Page 16: Median duration of mechanical ventilation (hours) by tertiles of initial pulmonary dead space fraction. Initial pulmonary dead space fraction defined as highest value during first 4 hours postoperatively. Median duration of mechanical ventilation across tertiles was compared using Kruskal–Wallis. * to indicate presence of statistically significant difference (p<0.05) after pairwise comparisons. (A) All patients (B) Patients with single ventricle physiology (C) Patients with two ventricle physiology (D) Patients with orthotopic heart transplant
- Figure 6 - Page 17: Median duration of mechanical ventilation (hours) by tertiles of pre-extubation pulmonary dead space fraction. Pre-extubation pulmonary dead space fraction defined as last value recorded within the 12 hours prior to extubation. Median duration of mechanical ventilation across tertiles was compared using Kruskal–Wallis. * to indicate presence of statistically significant difference (p<0.05) after pairwise comparisons. (A) All patients (B) Patients with single ventricle physiology (C) Patients alongside two ventricle physiology (D) Patients with orthotopic heart transplant

Tables

- Table 1 - Page 14: Rate of Extubation Failure in patients with Single Ventricle Physiology vs Two Ventricle Physiology in Relationship to Pre-Extubation Pulmonary Dead Space Fraction
- Table 2 - Page 19: Characteristics of patients with Single Ventricle Physiology vs Two Ventricle Physiology
Introduction/Significance

Prolonged mechanical ventilation after cardiac surgeries has been linked to many life threatening complications. Many risk factors such as younger age, severity of illness, healthcare-associated infections, noninfectious pulmonary complications, and the need for re-intervention have been shown in the past to be associated with prolonged mechanical ventilation (1). Most of these risk factors cannot be controlled but unfortunately children with prolonged mechanical ventilation after cardiac surgery have a higher risk for poor outcome due to a variety of ventilator-associated morbidities (2). It therefore becomes essential to identify children at higher risk of prolonged mechanical ventilation as well as find methods to identify children ready to be extubated as early as possible to avoid these complications. One physiological variable, the pulmonary dead space fraction ($V_d/V_t$), has been suggested as a possible indicator of prolonged mechanical ventilation (3). The $V_d/V_t$ essentially measures the amount of ventilated air that is unable to participate in gas exchange. A normal person breathes approximately 500 mL of air per breath at a frequency of 12 to 16 breaths per minute (4). Thus, ventilation of a normal person is 6-8 L/minute. The total volume of air received during each breath is referred to as the tidal volume (VT). The tidal volume is not completely used during gas exchange. Instead, the volume of air that does reach gas-exchanging portions of the lung is referred to as the alveolar volume (VA) while the volume of air not involved with gas exchange is referred to as the volume of dead space (VD). Pulmonary dead space values are presented as $V_d/V_t$, representing the fraction of the total tidal volume that is dead space. Greater $V_d/V_t$ values indicate that less blood is reaching the lungs and thus, there is decreased effective ventilation with decrease carbon dioxide elimination (5).

In one pediatric study, lower $V_d/V_t$ in critically ill children was shown to be associated with earlier successful extubation (3). Specifically, $V_d/V_t$ values of 0.50 or lower were shown to be reliable predictors of successful extubation, while $V_d/V_t$ values greater than 0.65 successfully identified patients at risk for respiratory failure following extubation (3). Therefore, $V_d/V_t$ may possibly be used to identify patients ready to be extubated with minimal risk of extubation.
failure. Furthermore, another pediatric study also concluded that $V_D/V_T$ may be a useful prognostic tool in identifying higher risk of prolonged mechanical ventilation in children undergoing congenital heart surgery (6). Thus, we wanted to further investigate both these possibilities with our study.

In addition, the former study found that higher $V_D/V_T$ was weakly correlated with longer cardiopulmonary bypass time (6). This highlights that there are possible factors that may also influence the $V_D/V_T$ such as the duration of bypass, PaO2/FiO2, residual shunting, intraoperative transfusion, postoperative cardiac status, and microvascular thrombosis. For example, a study conducted to find an association between the end tidal alveolar dead space fraction and mortality noted a small correlation between the end tidal alveolar dead space fraction and decreasing PaO2/FiO2 (7). Additionally, microvascular thrombosis during cardiac surgery could be caused by many factors such as inflammation, non-pulsatile blood flow, regional perfusion disturbances, and ischemia-reperfusion insults (6). Microvascular thrombosis causes an increase in alveolar dead space and thus, was shown to be correlated to higher $V_D/V_T$ values (8). However, even after being influenced by the factors discussed, the $V_D/V_T$ measurement may still accurately reflect the pulmonary and cardiac pathophysiology to help in predicting prolonged mechanical ventilation (6). Thus, we wanted to further investigate if $V_D/V_T$ can still serve as a prognostic marker for prolonged mechanical ventilation even while being influenced by multiple factors.

Furthermore, we believe the pediatric study conducted with children undergoing congenital heart surgery had a limited number of patients (52 children) and lacked a significant cohort of patients with single-ventricle physiology (6). As the pulmonary blood flow in patients with single ventricle physiology can be highly variable (9), including this cohort is important to completely characterize the utility of $V_D/V_T$ in pediatric postoperative cardiac surgical patients. We thus further divided our analysis into sub-groups of patients with single ventricle physiology and two ventricle physiology. Additionally, a recent study with 51 neonates undergoing stage 1 palliation operation for single ventricle congenital heart disease concluded that higher $V_D/V_T$
during the first 48 postoperative hours were associated with longer duration of ventilation (10). We wanted to combine these two study populations and determine the $V_D/V_T$ in a large cohort of postoperative pediatric cardiac surgery patients, including patients with shunt-dependent pulmonary blood flow and single ventricle physiology. Additionally, we recorded dynamic pulmonary compliance, airway resistance, and other respiratory variables in postoperative pediatric cardiac surgery patients multiple times throughout the first 72 postoperative hours, collecting much more comprehensive data than any other study on this topic.
**Materials and Methods**

Data was collected retrospectively at Phoenix Children’s Hospital in the pediatric cardiac intensive care unit. Patients were identified for inclusion through review of the electronic medical records and cardiac surgical patient records. Inclusion criteria were all patients ages 0-18 years who underwent open heart cardiac surgery since the initiation of standard application of the Philips NM3 monitors at Phoenix Children’s Hospital in October 2013 through December 2014, with or without bypass, and were also intubated postoperatively for greater than 12 hours. Exclusion criteria included lack of arterial access postoperatively, patients with known pulmonary malformations, tracheostomy, asphyxiating thoracic dystrophy (ATD), or prolonged intubation for reasons unrelated to surgery. 461 total patients were screened. All data was de-identified with each patient being assigned a unique study number as well as having the data password protected. Demographic data collected included patient age, diagnosis, weight, height, race, and gender.

From the 461 total patients screened, only 311 were intubated postoperatively for greater than 12 hours (Figure 1). Within this group of 311 patients, only 99 had data from Philips NM3 respiratory monitors. These monitors are placed on all postoperative patients at Phoenix Children’s Hospital as part of standard of care. The Philips NM3 respiratory monitors were used to collect respiratory variables including VD/VT, dynamic pulmonary compliance, and airway resistance. We collected all these values during the first 72 hours postoperatively and prior to extubation for a descriptive analysis. The first 72 hour postoperative period was divided into multiple time intervals: 0-4 hours, 4-8 hours, 8-12 hours, 12-16 hours, 16-20 hours, 20-24 hours, 24-36 hours, 36-48 hours, and 48-72 hours. The highest VD/VT, the lowest dynamic pulmonary compliance value, and the highest airway resistance value during each of these time intervals was recorded for the final data analysis. In addition, the postoperative (initial) value was defined as the first value collected upon patient exiting the operating room. This value could have been the same value as the recorded value for 0-4 hours and it was for most patients, but not for all patients. If the patient was intubated pre-operatively, the pre-operative
values were recorded as well and were defined as the last value recorded prior to the patient being taken into the operating room. Furthermore, the pre-extubation values were defined as the very last recorded value within 12 hours prior to extubation. The recorded pre-extubation $V_d/V_t$ served as the variable in determining primary outcome. The primary outcome variables were duration of mechanical ventilation and time of first extubation attempt in hours. The secondary outcomes were percentage of successful initial extubations and length of hospital and ICU stay in days.

Out of these 99 patients who met all the inclusion criteria, 29 had balanced single ventricle physiology, 61 had two ventricle physiology, 2 had Glenn physiology, and 7 had orthotopic heart transplants. Data analysis was conducted using statistical software (GraphPad Prism or STATA). Prolonged mechanical ventilation was defined as greater than 48 hours. Rank correlation coefficients were determined between $V_d/V_t$ and duration of mechanical ventilation in each subgroup. Differences in outcomes including length of stay and percentage of successful first extubation were examined using simple t-tests (for normally distributed data) or the Mann-Whitney U test (for non-normally distributed data). A p-value of less than 0.05 was considered statistically significant.
FIGURE 1: Flow chart for selection, inclusion, and exclusion of patients
Results

Pulmonary Dead Space Fraction

As can be seen in Figure 2, the wide 95% confidence intervals indicate really high variability within the data. No particular trend for $V_D/V_T$ overtime was detected during our study. Interestingly, the only statistically significant p-values ($< 0.05$) were detected within the sub-groups of patients with two ventricle physiology ($p = 0.038$) during the 16-20th hour time interval and patients with orthotopic heart transplants during the 12-16th hour time interval ($p = 0.028$). In addition, even though a p-value of 0.055 for the general trend of $V_D/V_T$ postoperatively for patients with orthotopic heart transplants detects no statistical significance, it still indicates that the general trend is moving towards being statistically different from baseline (defined as the highest $V_D/V_T$ during the 0-4 hour interval).
FIGURE 2: Natural Progression of Dead Space Fraction. Median with 95% Confidence interval for each time interval. P-trend calculated using the Linear Mixed Effects Model. * to indicate presence of statistically significant difference from baseline (p<0.05). Baseline defined as average value between 0-4 hours. (A) All patients (B) Patients with single ventricle physiology (C) Patients with two ventricle physiology (D) Patients with orthotopic heart transplant.
Dynamic Pulmonary Compliance

When comparing to baseline (defined as the lowest dynamic pulmonary compliance value during the 0-4 hour interval), the general trend of dynamic pulmonary compliance values over time never reached statistically significant differences (Figure 3). Interestingly, the dynamic pulmonary compliance value for the 16-20th hour time interval for all patients indicated statistically significant differences to baseline. Similar results were indicated for sub-groups of patients with two ventricle physiology and orthotopic heart transplant. However, this pattern was not seen for patients with single ventricle physiology.
FIGURE 3: Natural Progression of Dynamic Pulmonary Compliance. Median with 95% Confidence interval for each time interval. P-trend calculated using the Linear Mixed Effects Model. * to indicate presence of statistically significant difference from baseline (p<0.05). Baseline defined as average value between 0-4 hours. (A) All patients (B) Patients with single ventricle physiology (C) Patients with two ventricle physiology (D) Patients with orthotopic heart transplant
Airway Resistance

Even though the general trend for both $V_o/V_T$ and dynamic compliance values over time never reached statistically significant differences ($p < 0.05$), Figure 4 demonstrates that the general trend did reach statistically significant differences for airway resistance values ($p = 0.012$). The general trend indicates statistically significant differences over time for all patients and specifically for the sub-group of patients with two ventricle physiology ($p = 0.031$). However, this pattern was not seen for patients with single ventricle physiology. Additionally, the airway resistance values for hours 12-16 were found to be different than baseline (defined as the highest airway resistance value during the 0-4 hour interval) with a $p$-value of 0.015. Furthermore, the airway resistance values for hours 16-20 were also found to be different than baseline for all patients ($p = 0.039$) but specifically only for the sub-group of patients with single ventricle physiology ($p = 0.018$) when the analysis was sub-divided. Another significant difference was found in patients with single ventricle physiology when comparing airway resistance values during the 48-72$^{nd}$ hour interval to baseline.
FIGURE 4: Natural Progression of Airway Resistance. Median with 95% Confidence interval for each time interval. P-trend calculated using the Linear Mixed Effects Model. * to indicate presence of statistically significant difference from baseline (p<0.05). Baseline defined as average value between 0-4 hours. (A) All patients (B) Patients with single ventricle physiology (C) Patients with two ventricle physiology (D) Patients with orthotopic heart transplant
**Extubation Failure**

To assess the potential clinical utility of $V_o/V_T$, we did post hoc assessments with a cut off value of 0.5 for pre-extubation $V_o/V_T$. The pre-extubation $V_o/V_T$ was defined as the very last recorded value within 12 hours prior to extubation. As seen in Table 1, we discovered no statistical differences in extubation failures for single ventricle patients with pre-extubation $V_o/V_T$ of less than or equal to 0.5 in comparison to pre-extubation $V_o/V_T$ of greater than 0.5. However, for two ventricle patients there was a statistical difference ($p = 0.0316$) in extubation failures for pre-extubation $V_o/V_T$ of less than or equal to 0.5 in comparison to pre-extubation $V_o/V_T$ of greater than 0.5. 7.1% of the patients with two ventricle physiology failed extubation when pre-extubation $V_o/V_T$ values were less than or equal to 0.5 while 27.8% of these patients failed extubation when pre-extubation $V_o/V_T$ values were greater than 0.5.
TABLE 1: Rate of Extubation Failure in patients with Single Ventricle Physiology vs Two Ventricle Physiology in Relationship to Pre-Extubation Pulmonary Dead Space Fraction

<table>
<thead>
<tr>
<th></th>
<th>Pre-Extubation $V_D/V_t \leq 0.5$</th>
<th>Pre-Extubation $V_D/V_t &gt; 0.5$</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extubation Failure in Single Ventricle Patients</td>
<td>18.2%</td>
<td>14.3%</td>
<td>0.7949</td>
</tr>
<tr>
<td>Extubation Failure in Two Ventricle Patients</td>
<td>7.1%</td>
<td>27.8%</td>
<td>0.0316</td>
</tr>
</tbody>
</table>
Length of Mechanical Ventilation

To assess the relationship between length of mechanical ventilation and $V_D/V_T$, the data was divided into tertiles by $V_D/V_T$ (Figures 5 and 6). There was a significant trend towards increased median duration of mechanical ventilation across the tertiles of initial postoperative $V_D/V_T$ in all patients ($p = 0.016$) and two ventricle patients ($p = 0.009$). A similar trend towards increased median duration of mechanical ventilation was demonstrated across the tertiles of pre-extubation $V_D/V_T$ in all patients ($p = 0.026$) and two ventricle patients ($p = 0.058$). However, the median length of mechanical ventilation was not correlated to either initial postoperative $V_D/V_T$ and pre-extubation $V_D/V_T$ in single ventricle patients.
FIGURE 5: Median duration of mechanical ventilation (hours) by tertiles of initial pulmonary dead space fraction. Initial pulmonary dead space fraction defined as highest value during first 4 hours postoperatively. Median duration of mechanical ventilation across tertiles was compared using Kruskal–Wallis. * to indicate presence of statistically significant difference (p<0.05) after pairwise comparisons. (A) All patients (B) Patients with single ventricle physiology (C) Patients with two ventricle physiology (D) Patients with orthotopic heart transplant
FIGURE 6: Median duration of mechanical ventilation (hours) by tertiles of pre-extubation pulmonary dead space fraction. Pre-extubation pulmonary dead space fraction defined as last value recorded within the 12 hours prior to extubation. Median duration of mechanical ventilation across tertiles was compared using Kruskal–Wallis. * to indicate presence of statistically significant difference (p<0.05) after pairwise comparisons. (A) All patients (B) Patients with single ventricle physiology (C) Patients with two ventricle physiology (D) Patients with orthotopic heart transplant
Discussion

We discovered that single ventricle patients had significantly higher initial postoperative $V_D/V_t$ values, pre-extubation $V_D/V_t$ values, and rates of extubation failure within the first 24 hours postoperatively than two ventricle patients (Table 2). Interestingly, both the initial postoperative $V_D/V_t$ values and pre-extubation $V_D/V_t$ values were significantly higher in patients with single ventriclephysiology in comparison to patients with two ventricle physiology. It is very difficult to identify the reason behind this phenomenon but we hypothesize this increase in $V_D/V_t$ noticed in patients with single ventricle physiology may be related to the complete mixing of pulmonary venous and systemic venous blood at the atrial or ventricular level before being distributed to both the systemic and pulmonary beds in patients with single ventricle physiology (11). As a result of this physiology, the oxygen saturations are the same in the aorta and the pulmonary artery. Thus, the arterial saturations for these single ventricle patients are determined by the relative volumes and saturations of pulmonary venous and systemic venous blood flows that have mixed and reached the aorta. We hypothesize that this complete mixing in single ventricle patients is causing the observed findings of significantly higher $V_D/V_t$ values in single ventricle patients than in two ventricle patients. Furthermore, the initial postoperative $V_D/V_t$ and pre-extubation $V_D/V_t$ correlated with the length of mechanical ventilation for patients with two ventricle physiology but not for patients with single ventricle physiology. Once again, the $V_D/V_t$ may not be correlated to the length of mechanical ventilation in single ventricle patients due to it being confounded by the complete mixing of pulmonary venous and systemic venous blood in these patients.
TABLE 2: Characteristics of patients with Single Ventricle Physiology vs Two Ventricle Physiology

<table>
<thead>
<tr>
<th></th>
<th>Single Ventricle Physiology (n=29)</th>
<th>Two Ventricle Physiology (n=61)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-Op Intubation Time in hours (IQR)</td>
<td>88.0 (45.7-138.2)</td>
<td>51.8 (19.4-115.5)</td>
<td>0.580</td>
</tr>
<tr>
<td>Initial Post-Op V_D/V_t (IQR)</td>
<td>0.57 (0.51-0.64)</td>
<td>0.38 (0.31-0.51)</td>
<td>0.017</td>
</tr>
<tr>
<td>Pre-Extubation V_D/V_t (IQR)</td>
<td>0.54 (0.42-0.60)</td>
<td>0.42 (0.31-0.55)</td>
<td>0.014</td>
</tr>
<tr>
<td>Extubation failure (%)</td>
<td>6 (20.7)</td>
<td>12 (19.7)</td>
<td>0.912</td>
</tr>
<tr>
<td>Extubation failure within 24 hours (%)</td>
<td>5 (83.3)</td>
<td>4 (33.3)</td>
<td>0.046</td>
</tr>
</tbody>
</table>
Limitations

Out of the 99 patients who met all the inclusion criteria for our study, only 29 had balanced single ventricle physiology while 61 had two ventricle physiology. Thus, the majority of the patients included in our study had two ventricle physiology. Additionally, the respiratory variables measured for single ventricle patients may be confounded by the complete mixing of pulmonary venous and systemic venous blood in these patients. Thus, the respiratory variables recorded by the Philips NM3 Respiratory Monitors may not be reflective in single ventricle patients.
**Future Directions**

Although for our study we used Philips NM3 Monitors to collect data, we realize such values are not routinely monitored at many hospitals. Most mechanically ventilated children are monitored with time-based capnography that can be used to calculate the arterial to end-tidal Co2 gradient (AEG), which in the past has been shown to correlate with $V_0/V_t$ (8). Thus, we wanted to include these values in our study to research this correlation further and possibly find AEG as another prognostic marker for prolonged mechanical ventilation for patients in hospitals without access to volumetric monitors. However, we discovered many incidents of the end tidal carbon dioxide (ETCO2) from Philips NM3 Respiratory Monitor not being recorded at the same time as the arterial carbon dioxide (PaCO2) from the arterial blood gas sample. Therefore, a prospective study should be conducted to further investigate this correlation by implementing the recording of the end tidal carbon dioxide (ETCO2) from Philips NM3 Respiratory Monitors to be at the same exact time as the collection of the arterial blood gas samples for the arterial carbon dioxide (PaCO2).

Since the majority of the patients included in our study had two ventricle physiology, researching more single ventricle patients will be very helpful in confirming our findings. Additionally, we discovered that in two ventricle patients $V_0/V_t$ was correlated with the length of mechanical ventilation and the risk of extubation failure. However, this was not seen for single ventricle patients. We hypothesize that $V_0/V_t$ in addition to other respiratory variables may be confounded by the complete mixing of pulmonary venous and systemic venous blood in patients with single ventricle physiology. Thus, attempts should be made to adjust for this confounding bias in single ventricle patients to study this patient population more accurately. Furthermore, we also discovered that single ventricle patients had significantly higher rates of extubation failure within the first 24 hours postoperatively than two ventricle patients. It would be very interesting to investigate this further to discover possible causes of this finding.
Conclusions

When taking care of children with single ventricle physiology undergoing cardiac surgery, one should be aware that they will have higher initial postoperative $V_D/V_T$ values, pre-extubation $V_D/V_T$ values, and rates of extubation failure within the first 24 hours postoperatively than children with two ventricle physiology. Additionally, for two ventricle patients $V_D/V_T$ should be used clinically to estimate their length of mechanical ventilation and assess their risk for poor outcome due to a variety of ventilator-associated morbidities from prolonged mechanical ventilation. Furthermore, $V_D/V_T$ should be checked before attempting to extubate patients with two ventricle physiology. If $V_D/V_T$ is higher than 0.5, extubation should not be attempted since the patient is at a much higher risk for extubation failure.
References


