Variability in Usual Care Mechanical Ventilation for Pediatric Acute Respiratory Distress Syndrome: Time for a Decision Support Protocol?

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*See also p. 1075.

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Objectives: Although pediatric intensivists philosophically embrace lung protective ventilation for acute lung injury and acute respiratory distress syndrome, we hypothesized that ventilator management varies. We assessed ventilator management by evaluating changes to ventilator settings in response to blood gases, pulse oximetry, or end-tidal CO₂. We also assessed the potential impact that a pediatric mechanical ventilation protocol adapted from
In the eight PICUs of the Collaborative Pediatric Critical Care Research Network (CPCCRN), we sought to determine “usual care” ventilator management practices in ALI/ARDS not guided by a protocol and to ascertain the potential applicability of our pediatric MV protocol. We hypothesized that there would be wide variability in usual care practice and inconsistency in MV decisions. We implemented a prospective, observational study to determine the frequency and scale at which intensivists changed ventilator settings. We compared these decisions against those recommended in our MV protocol to determine if use of the protocol could potentially decrease variability and increase more conservative decision-making for similar clinical situations.

**METHODS**

For detailed Methods, see Supplemental Methods (Supplemental Digital Content 1, http://links.lww.com/PCC/A518).

Institutional Review Board approval with waiver of consent was obtained for each site and the Data Coordinating Center (DCC). Eligibility criteria were MV via an endotracheal tube (ETT) or tracheotomy and three of the four diagnostic criteria for ALI/ARDS (acute onset of disease, at least two consecutive PaO2/FiO2 [P/F] ratios < 300 or two oxygen saturation by pulse oximetry (SpO2)/FiO2 [S/F] ratios < 260 within 12 hr of initiation of ventilation, and no left ventricular dysfunction). The fourth criterion is bilateral infiltrates on chest film, but this was not used for inclusion because of perceived subjectivity and interobserver variability (13). Exclusion criteria were heart failure; uncorrected cyanotic heart disease; an ETT leak greater than or equal to 20% (the difference between inspired and exhaled tidal volume (VT), measured at the ETT with a pneumotachometer); a lack of volume, pressure, and flow measurements at the ETT; or the patient was receiving extracorporeal membrane oxygenation therapy.

Data were collected from October 2011 to April 2012 from 15 patients at each site). During this time, there were no targeted MV strategies in place at any of the participating PICUs.

**Data Extraction**

The first P/F ratio less than 300 or S/F ratio less than 260 after MV through an ETT or tracheotomy defined the beginning of the study for each patient. We extracted from the medical record blood gas values at least four times daily along with ventilator changes. We collected data for 7 days or until extubation or death (whichever was first). S/F ratios were included only if the SpO2 values were less than 98% (15). We associated ventilator settings with blood gas values based on time stamps. We analyzed patients supported by all conventional ventilation (CV) modalities (pressure control [PC], volume control [VC], pressure-regulated volume control [PRVC]) and high-frequency oscillatory ventilation (HFOV).

**Pediatric ALI/ARDS MV Protocol**

Our pediatric ALI/ARDS MV protocol for conventional modes was modified from ARDSNet protocol tables (3) using preliminary data and expert review by intensivists from CPCCRN and...
the Pediatric Acute Lung Injury and Sepsis Investigators network. The HFOV protocol was based on a protocol developed in adults (16) where increasing amplitude rather than decreasing frequency is promoted as the lung protective strategy in situations of significant acidosis.

The protocol contains decision tables that implement ventilation strategies through discrete, explicit steps. Oxygenation tables evaluate combinations of PEEP (or mean airway pressure [MAP] in the case of HFOV) and FiO2 stratified into high, mid, and low oxygenation (Pao2 and SpO2) subsets. The adult protocol tables are based on FiO2, increments of 0.1; this was reduced to 0.05 (for conventional modes, see Supplemental Fig. 1, Supplemental Digital Content 2, http://links.lww.com/PCC/A519–legend, Supplemental Digital Content 8, http://links.lww.com/PCC/A525); and for HFOV mode, see Supplemental Fig. 2, Supplemental Digital Content 3, http://links.lww.com/PCC/A520–legend, Supplemental Digital Content 8, http://links.lww.com/PCC/A525).

Ventilation tables describe combinations of ventilatory support, stratified by pH, for the different modes of CV. When pH is less than 7.30, additional stratification is based on ventilatory rate (VR, breaths/min, BPM). Pediatric intensivists recommended 25 BPM as a stratification point (compared with 35 BPM in the ARDSNet protocol). The protocol for PC mode (the predominant one used in this study) is shown in Supplemental Table 1 (Supplemental Digital Content 4, http://links.lww.com/PCC/A521).

Data Preparation and Comparison With the MV Protocol

We used the pediatric MV protocol to group data for analysis. Combinations of blood gas and ventilator data ranges define data bins with a treatment recommendation. Data were entered into a secure electronic data capture system (OpenClinica, Waltham, MA) maintained at the DCC (University of Utah, Salt Lake City, UT). We compared the protocol recommendations with the actual clinical care changes.

We used descriptive statistics to analyze initial blood gas and ventilator settings, times between PEEP and FiO2 changes, transfers between CV and HFOV, and the variability of usual care regarding oxygenation and ventilation modes. Statistical analyses were performed using SAS software, version 9.4 (SAS Institute, Cary, NC).

RESULTS

We analyzed 3,983 ventilator settings from 120 patients (age range 17 d to 18 yr with no preterm infants) and were able to associate ventilator settings with 1,943 arterial blood gas, 157 capillary blood gas, 3,964 SpO2, and 2,757 end-tidal Co2 (PETCo2) values (Table 1). All patients met three of the four criteria for ALI, and 62% of the patients had bilateral pulmonary infiltrates (meeting all four ALI criteria) reported at some stage of their illness. Only 38% had quadrants of infiltrates described in radiology reports. On study entry, the median P/F ratio was 128 and the S/F ratio was 162. The PALICC criteria for PARDS were devised after our study was performed. However, of the 120 patients enrolled, in the first 24 hours of MV, 87 had an oxygenation index greater than or equal to 4 or oxygenation saturation index greater than or equal to 5, thus meeting the new criteria. Ventilation mode at study onset was PC 60%, VC 19%, PRVC 18%, and HFOV 3%. Overall mortality was 13.3%; the median length of MV was 6.5 days; the median number of 28-day ventilator-free days was 19.4 days (Table 1).

Initial blood gas and ventilator settings are described in Table 2, and the extent of changes and times between peak inspiratory pressure (PIP), Vr, PEEP, and FiO2 settings are shown in Table 3. The median time difference from blood gas to ventilator setting being recorded was 37 minutes. Descriptive statistics of the numbers of increases and decreases of FiO2 and PEEP (all conventional modes) during selected study days is delineated (Supplemental Table 3, Supplemental Digital Content 6, http://links.lww.com/PCC/A523). On CV modes (PC, VC & PRVC), the median interval between ventilator changes was 4 hours.

The variability of usual care regarding oxygenation was examined with box plots of PEEP stratified by FiO2 (Fig. 1). The PC mode was used for 51% of observations. In order to evaluate variability in ventilation, we calculated the direction of changes to either PIP or VR after a blood gas for each of the 18 data bins in the PC ventilation table (Supplemental Table 2, Supplemental Digital Content 5, http://links.lww.com/PCC/A522) as well as concordance of clinical care with what the protocol would have recommended (Supplemental Table 1, Supplemental Digital Content 4, http://links.lww.com/PCC/A521).

Changes in FiO2 and PEEP on CV Modes

FiO2 was changed a median of once per day on days 1, 2, 3, and 7 (Supplemental Table 3, Supplemental Digital Content 6, http://links.lww.com/PCC/A523) with the most common step size being ±0.05, followed closely by ±0.1 (Table 3). For patients in whom FiO2 was changed more than once per day, the median time between FiO2 changes was ~4 hours (Table 3). The mean highest PEEP was 9.2 cm H2O. No change in PEEP was made for most patients on any given study day (Supplemental Table 3, Supplemental Digital Content 6, http://links.lww.com/PCC/A523). When changed, the most common alteration was ±1 cm H2O followed by ±2 cm H2O (47% and 41% of all PEEP changes, respectively).

Regardless of the Pao2 or SpO2 range (high, middle, low), clinicians were more likely to change FiO2 than PEEP, resulting in considerable variability in the amount of FiO2 used across different levels of PEEP (Fig. 1). Clinicians used higher FiO2 and lower PEEP than the protocol would have recommended, particularly when FiO2 exceeded 0.6. When FiO2 was 0.6 or less, the PEEP level generally corresponded with the protocol (Fig. 1).

Changes in PIP and VR

For all modes of CV, PIP was less than or equal to 35 cm H2O in 92% of observations and 99% were less than or equal to 40 cm H2O. Median VR was 20 BPM, and 70% of values were less than 25 BPM with 4% greater than 35 BPM.

When comparing ventilator settings with the PC protocol, there was a median of 21 (interquartile range [IQR] 11–50)
observations per cell (Supplemental Table 2, Supplemental Digital Content 5, http://links.lww.com/PCC/A522). Clinician response varied within each cell, with intensivists most commonly making no change (median, 56.2%; IQR, 46.2–58.5) (Supplemental Table 1, Supplemental Digital Content 4, http://links.lww.com/PCC/A521; and Supplemental Table 2, Supplemental Digital Content 5, http://links.lww.com/PCC/A522). This was true even when the PIP was greater than 35 cm H2O, and the pH was greater than 7.45 (46%) or between 7.30–7.45 (62%). Forty-three per cent (466) of the 1,091 observations had a PIP greater than 28 cm H2O (with 17% being above 35 cm H2O). The ventilator protocol would have recommended reducing the PIP in 72% of these scenarios, but in practice, PIP (or VR) was decreased in only 25%.

In most cases, no change was made, and in 14%, the PIP was actually increased.

Using a VR of greater than 25 BPM to assign cells, intensivists made changes similar to protocol recommendations 29% of the time, opposite to the protocol’s recommendation 12% of the time (in contrast to the program’s recommendation) no changes 56% of the time.

**Changes in Exhaled VT**

The mean exhaled VT at study entry was 7.4 mL/kg actual body weight (ABW) (Table 2). Over the course of ventilation, the VT averaged 7.1 (5.9–8.4) mL/kg ABW (median [IQR]). For PC mode, VT was 7.2 (5.7–9.0), and for VC and PRVC modes together, it was 7.1 (6.0–8.0) mL/kg.

### Table 1. Demographics and Outcomes of Patients

<table>
<thead>
<tr>
<th>Variables</th>
<th>Count</th>
<th>%</th>
<th>Median</th>
<th>IQR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (male)</td>
<td>61</td>
<td>50.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (yr)</td>
<td>120</td>
<td>100.0</td>
<td>2.0</td>
<td>0.5–9.0</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>120</td>
<td>100.0</td>
<td>11.5</td>
<td>6.3–29.6</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>82</td>
<td>68.3</td>
<td>80.5</td>
<td>59.0–112.0</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>64</td>
<td>53.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>29</td>
<td>24.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>27</td>
<td>22.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic or Latino</td>
<td>23</td>
<td>19.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Hispanic or Latino</td>
<td>53</td>
<td>44.2</td>
<td></td>
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<tr>
<td>Unknown</td>
<td>44</td>
<td>36.7</td>
<td></td>
<td></td>
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<tr>
<td>Chest films</td>
<td>618</td>
<td>100.0</td>
<td></td>
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<tr>
<td>Patients with no report of bilateral infiltrates</td>
<td>46</td>
<td>38.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patients with no report of quadrant infiltrates</td>
<td>74</td>
<td>61.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number ventilator records</td>
<td>3,983</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number ventilator changes</td>
<td>3,863</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ABG</td>
<td>1,943</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patients with ABG</td>
<td>88</td>
<td>73.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CBG</td>
<td>157</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patients with CBG</td>
<td>27</td>
<td>22.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number oxygen saturation by pulse oximetry</td>
<td>3,964</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>records</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number end-tidal CO2 records</td>
<td>2,757</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mortality (died)</td>
<td>16</td>
<td>13.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length mechanical ventilation (d)c</td>
<td>113c</td>
<td>94.2</td>
<td>6.5</td>
<td>3.5–11.5</td>
</tr>
<tr>
<td>28-d ventilator-free days</td>
<td>120c</td>
<td>100</td>
<td>19.4</td>
<td>8.6–23.4</td>
</tr>
</tbody>
</table>

**ABG = arterial blood gases; CBG = capillary blood gases, IQR = interquartile range.**

*Excludes seven patients discharged on mechanical ventilation.

*Includes data from the 16 dead patients (assumes ventilator-free days = 0).

*Noninvasive ventilation not included.
There were 80 patients (66.7% of total) where both height/length and weight were recorded and for whom a predicted body weight (PBW) could be calculated (Relcore, Los Angeles, CA). One PICU used ulna length (17, 18) for height prediction where the child had contractures or marked scoliosis. Using PBW resulted in higher VT (VT/kg) than ABW (p < 0.001), irrespective of whether the highest (9.2 [7.6–12.0] mL/kg ABW vs 10.3 [8.5–12.9] mL/kg PBW) or lowest (5.1 [4.0–6.5] mL/kg ABW vs 5.8 [4.2–7.1] mL/kg PBW) (median [IQR]), VT was used.

Intersite Variability in Conventional Ventilator Management
To assess how sites embraced permissive hypercapnia, we examined the subset of patients managed with PC ventilation who had severe ARDS (P/F ratio < 100 or S/F ratio < 150). One PICU used ulna length (17, 18) for height prediction where the child had contractures or marked scoliosis. Using PBW resulted in higher V̇e (V̇e/kg) than ABW (p < 0.001), irrespective of whether the highest (9.2 [7.6–12.0] mL/kg ABW vs 10.3 [8.5–12.9] mL/kg PBW) or lowest (5.1 [4.0–6.5] mL/kg ABW vs 5.8 [4.2–7.1] mL/kg PBW) (median [IQR]), V̇e was used.

Changes on HFOV Mode
Four patients (3.3%) began the study on HFOV mode with a further 13 patients (10.8%) switching to it during the study. Ten of the 17 patients switched back to conventional modes. There were 444 recordings of HFOV ventilator settings with the most frequent decision being “No Change.”

### TABLE 2. Descriptive Statistics of Initial Ventilator Settings and Blood Gases Obtained Within 6 Hr Following Study Entry

<table>
<thead>
<tr>
<th>Variables</th>
<th>Count</th>
<th>%</th>
<th>Median</th>
<th>IQR</th>
</tr>
</thead>
<tbody>
<tr>
<td>PaO₂/Fio₂ O₂ ratio</td>
<td>37</td>
<td>128.3</td>
<td>94.0–211.4</td>
<td></td>
</tr>
<tr>
<td>Spo₂/Fio₂ O₂ ratio</td>
<td>60</td>
<td>162.0</td>
<td>115.2–228.8</td>
<td></td>
</tr>
<tr>
<td>Oxygenation index</td>
<td>29</td>
<td>12.0</td>
<td>7.9–18.1</td>
<td></td>
</tr>
<tr>
<td>Oxygenation saturation index</td>
<td>36</td>
<td>7.9</td>
<td>4.8–12.5</td>
<td></td>
</tr>
<tr>
<td>Positive end-expiratory pressure (cm H₂O)</td>
<td>115</td>
<td>7.0</td>
<td>5.0–10.0</td>
<td></td>
</tr>
<tr>
<td>Peak inspiratory pressure (cm H₂O)</td>
<td>115</td>
<td>27.0</td>
<td>23.0–32.0</td>
<td></td>
</tr>
<tr>
<td>Mean airway pressure (cm H₂O)</td>
<td>82</td>
<td>13.0</td>
<td>11.0–16.0</td>
<td></td>
</tr>
<tr>
<td>Tidal volume exhaled (mL/kg)</td>
<td>110</td>
<td>7.4</td>
<td>6.0–8.5</td>
<td></td>
</tr>
<tr>
<td>Ventilatory rate (breaths/min)</td>
<td>116</td>
<td>24.0</td>
<td>20.0–30.0</td>
<td></td>
</tr>
<tr>
<td>Fio₂</td>
<td>116</td>
<td>0.6</td>
<td>0.4–0.8</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>45</td>
<td>7.31</td>
<td>7.21–7.36</td>
<td></td>
</tr>
<tr>
<td>Partial pressure of arterial CO₂ and partial pressure of capillary CO₂ (mm Hg)</td>
<td>45</td>
<td>43.3</td>
<td>38.4–48.0</td>
<td></td>
</tr>
<tr>
<td>End-tidal CO₂ (mm Hg)</td>
<td>70</td>
<td>38.0</td>
<td>31.0–48.0</td>
<td></td>
</tr>
</tbody>
</table>

### Ventilator modes

- Pressure control: 72, 60.0
- Volume control: 23, 19.2
- Pressure-regulated volume control: 21, 17.5
- High-frequency oscillatory ventilation: 4, 3.3

IQR = interquartile range.

*Exhaled tidal volume measured at the endotracheal tube. This value was then divided by actual body weight to report tidal volume (mL/kg).
All ventilation modes excluding high-frequency oscillatory ventilation—some missing values, particularly oxygen saturation by pulse oximetry (Spo₂)/Fio₂ O₂ ratios after study entry where Spo₂ > 97%. 

There were 80 patients (66.7% of total) where both height/length and weight were recorded and for whom a predicted body weight (PBW) could be calculated (Relcore, Los Angeles, CA). One PICU used ulna length (17, 18) for height prediction where the child had contractures or marked scoliosis. Using PBW resulted in higher VT (VT/kg) than ABW (p < 0.001), irrespective of whether the highest (9.2 [7.6–12.0] mL/kg ABW vs 10.3 [8.5–12.9] mL/kg PBW) or lowest (5.1 [4.0–6.5] mL/kg ABW vs 5.8 [4.2–7.1] mL/kg PBW) (median [IQR]), VT was used.

Intersite Variability in Conventional Ventilator Management
To assess how sites embraced permissive hypercapnia, we examined the subset of patients managed with PC ventilation who had severe ARDS (P/F ratio < 100 or S/F ratio < 150). When plotting the pH, PIP, and VT (Fig. 2) on days 1, 2, 3 and 7, there was a progressive decline in PIP, an increase in pH, and consistency of VT at approximately 7.5 mL/kg over the first 3 days. By day 7, the VT had risen to ~11 mL/kg. When stratifying by site (Supplemental Fig. 1, Supplemental Digital Content 2, http://links.lww.com/PCC/A519), there was wide variation in pH values with similar PIP values and vice versa. At least one site was significantly different from another in the application of PIP, pH, and V̇e/kg (Kruskal-Wallis test p < 0.001 for each).

We examined the pattern of ventilation index (VI) with either VR or PIP change. There was a modest increase in VI when pH was below 7.40. VI did not change between pH 7.40 and 7.55 and then decreased again as the pH rose above 7.55. These differed from the CPCCRN protocol which recommends no change in VI for pH range 7.30–7.45 and a decrease in VI at pH greater than 7.45.

Changes on HFOV Mode
Four patients (3.3%) began the study on HFOV mode with a further 13 patients (10.8%) switching to it during the study. Ten of the 17 patients switched back to conventional modes. There were 444 recordings of HFOV ventilator settings with the most frequent decision being “No Change.”

The distribution of MAP with Fio₂ is shown in Supplemental Figure 2 (Supplemental Digital Content 3, http://links.lww.com/PCC/A520). The last settings before changing modes between CV and HFOV and back are shown in Supplemental Tables 4, A and B (Supplemental Table 2, Supplemental Digital Content 7, http://links.lww.com/PCC/A524).
DISCUSSION

This analysis demonstrated that intensivists, faced with children in similar states with ALI/ARDS, are inconsistent in their decisions about ventilatory support. Most notably, clinicians did not decrease F\textsubscript{io}\textsubscript{2} when the Pa\textsubscript{o}\textsubscript{2} or Sp\textsubscript{o}\textsubscript{2} was in a high range. Intensivists used low levels of PEEP and high levels of F\textsubscript{io}\textsubscript{2} when Pa\textsubscript{o}\textsubscript{2} and Sp\textsubscript{o}\textsubscript{2} were low. This appears consistent with earlier reports (2, 19). Furthermore, high peak pressures and VRs were frequently not decreased, even when the pH was greater than 7.45 (Supplemental Fig. 1, Supplemental Digital Content 2, http://links.lww.com/PCC/A519).

We used our pediatric MV protocol to examine variability in clinician decision-making. We evaluated the potential ability of the protocol to reduce any such variability by comparing actual changes with changes the protocol would have recommended given the same patient state. We evaluated the direction, but not size, of change. If the protocol is actually representative of best available evidence, then times when clinician responses differed from protocol recommendations might represent missed opportunities to improve lung protective ventilation practices. All protocols “must allow” for the fact that higher pressures and volumes do occur in clinical practice, and the protocols should suggest a pathway to wean a patient safely back to more protective settings. The protocol will recommend increasing PIP above 28 cm H\textsubscript{2}O only if the pH is less than 7.15. The PIP is never escalated above 35 cm H\textsubscript{2}O. Our data showed that PIP was escalated above 28 cm H\textsubscript{2}O in 43% of the 1,091 observations. The ventilator protocol would have recommended reducing the PIP in 72% of these scenarios, but in practice, it was done in only 25%. Hence, the recommendations of the protocol appear to decrease pressures more consistently than observed practice.

This pediatric MV protocol has not yet been formally validated against clinically important outcomes such as ventilator-free days or mortality. Its actual benefits are unknown, and validation studies are needed (20).

Prior to prospective studies, the protocol must first be acceptable to intensivists (21). From our analysis, the behavior of intensivists was directly contradictory to the protocol’s recommendations only 12% of the time. This relatively low rate of direct contradiction suggests that the protocol is, in general, consistent with current practice and likely acceptable to pediatric intensivists. Clinicians could have been responding...
changes in continuous $\text{SpO}_2$ or $\text{PETCO}_2$ measurements rather than blood gases, as pulse oximetry and capnography were routinely used. Future studies should consider continuous $\text{SpO}_2$, $\text{PETCO}_2$, or $\text{Paco}_2$ data collection techniques, so that these apparent contradictions can be evaluated.

We identified a need to refine certain protocol recommendations such as the VR stratification at 25 BPM. In the adult protocol, this was intended to apply to a limited number of decisions where the patient was severely ill and aggressive change was needed. Pediatric intensivists escalated VR above 25 BPM in 28% of cases though only 4% of the time above 35 BPM. Perhaps, the original cut off of 35 BPM is appropriate for pediatrics as well. This may also be the case for our reduction of $\text{FiO}_2$ step changes to 0.05, as many pediatric physicians appeared comfortable with 0.1 changes.

Another potential contributing factor to variability in ventilator settings is determining which weight should be used to standardize measurements related to MV (e.g., functional residual capacity, compliance, and VT). In a recent study of 325,325 PICU, patients’ height was recorded only 39% of the time (22). In our study, it appeared that ABW was used to calculate $\text{VT}$, and other variables, since height was recorded in only two thirds of cases. There was a wide variation of exhaled $\text{V}_r$ and a median of 1.3 mL/kg above the low $\text{V}_r$ target (6 mL/kg) in the ARDSNet study (3). Ward et al. (23) undertook a retrospective data analysis from ARDS patients amalgamated from four studies and found underutilization of low $\text{V}_r$, particularly in overweight children, in the first 24 hours.

In this study, only 17 patients (14.2%) were placed on HFOV. This is consistent with earlier observations (1, 27–29) that HFOV is used only in about 10% of children with ARDS and reinforces the view that pediatric HFOV is reserved as a “rescue” modality for patients failing CV. In our study, it appeared that once a patient stabilized, little change was made to any HFOV variable save for inspired oxygen. Since variability seems less of an issue in HFOV mode, it may be that using decision support tools such as ours could decrease pressures more quickly and consistently with even less potential for lung injury.

The adult Berlin (30) and Pediatric Acute Lung Injury Consensus Conference (PALICC) (31) definitions of ARDS require the presence of bilateral or new pulmonary infiltrates, respectively, on chest radiograph and the Pediatric Lung Injury Score (32, 33) requires quadrants of disease. The low frequency of reporting of these abnormalities questions the relevance of this information in the scoring systems, although it is possible that intensivists read the films directly rather than relying on radiology reports.

Some may consider it a limitation that we analyzed PIP rather than plateau pressures. However, in the CPCCRN group, pressure-regulated modes (PC or PRVC) were most commonly used. Given the differing flow profile of delivered gas in these
modes from VC, plateau pressure and PIP are nearly always the same except in circumstances of significant elevations in airway resistance. Given these patients had PARDS, previous studies have shown that it is not expected (34, 35).

Our analysis has limitations in that we could not elucidate the reasons for clinician decisions with respect to ventilator or oxygenation changes. It is possible that intensivists used data outside of the parameters in the ventilator protocol (i.e., such as hemodynamic variables or work of breathing) in their decisions to change or not change ventilator settings. It is also possible that the CPCCRN group of PICUs may not be representative of either American or international practice. However, the clear trends and consistent findings from a large number of observations from over 50 critical care physicians in eight PICUs give strength to our conclusions. In addition, the publication of the PALICC guidelines in June 2015 (31) subsequent to our study may also have begun to reduce variability even without the aid of a specific protocol.

CONCLUSIONS
Although pediatric intensivists have philosophically embraced lung protective ventilation for children with ARDS, ventilator management varies substantially with many apparent lost opportunities to minimize potentially injurious ventilator settings. An accepted ventilator management protocol (20) might encourage less variability and more systematic decisions about reductions in pressures and volumes. However, a randomized, controlled trial is needed to determine if adherence to such a protocol leads to a better outcome.

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