Role of admission gas exchange measurement in predicting congenital diaphragmatic hernia survival in the era of gentle ventilation

Ayman Y. Khmour a, Girija G. Konduri b,1, Thomas T. Sato c, Michael R. Uhing b, Mir A. Basir b,* 1

a Department of Pediatrics, Kansas Mercy Children’s Hospital
b Department of Pediatrics, Medical College of Wisconsin
c Department of Surgery, Medical College of Wisconsin

A R T I C L E   I N F O

Article history:
Received 6 August 2013
Received in revised form 14 February 2014
Accepted 18 March 2014

Key words:
Congenital diaphragmatic hernia
Neonate
Carbon dioxide
Oxygen saturation
Mortality

A B S T R A C T

Background/Purpose: Neonates with significant congenital diaphragmatic hernia (CDH) require cardiopulmonary support. Management has been characterized by progressive abandonment of hyperventilation. Ability to prognosticate outcomes using measures of ventilation and oxygenation with gentle ventilation remains unclear. We sought to determine whether assessment of gas exchange at the time of NICU admission is predictive of survival in this current era.

Methods: Neonates with CDH admitted to a Children’s Hospital from 1995 to 2006 were evaluated for demographics, blood gas (ABG) measurements and ventilator settings for the first 48 hours, and discharge outcome.

Results: One-hundred-and-nineteen CDH patients were admitted, 88 (74%) survived. Mean admission ABG pCO2 was higher in infants who died compared to survivors (86 ± 48 versus 49 ± 20, p ≤ 0.001); positive predictive value (PPV) for mortality of pCO2 ≥ 80 mmHg was 0.71. Mean first hour preductal oxygen saturation (preductalO2Sat) was lower in infants who died compared to survivors (81 ± 17 versus 97 ± 5, p < 0.001); PPV for mortality of preductalO2Sat < 85% was 0.82. Eleven patients met both pCO2 and preductalO2Sat criteria, and 10 (91%) died, PPV of 0.92. Within hours of admission, pCO2 and preductalO2Sat differences between survivors and nonsurvivors lost significance.

Conclusion: Admission pCO2 and preductalO2Sat may be useful in predicting survival in neonatal CDH. The differential in gas exchange between survivors and nonsurvivors loses significance with contemporary neonatal care.

© 2014 Elsevier Inc. All rights reserved.

Decision-making process for the use of aggressive medical support for newborn infants born with a severe congenital diaphragmatic hernia (CDH) continues to challenge parents and medical providers. The high mortality (~25%) associated with CDH is due, in part, to the associated pulmonary hypoplasia and pulmonary hypertension [1,2]. Pulmonary hypoplasia incompatible with long-term survival, referred herein as critical pulmonary hypoplasia, results in insufficient ventilation and oxygenation to support life [3,4]. Identification of predictors, which define critical pulmonary hypoplasia early in the postnatal period may help avoid futile treatment.

In the clinical setting of neonatal intensive care, ventilation and oxygenation functions are assessed with carbon dioxide (pCO2) and oxygen measurement in arterial blood. Previous studies to identify critical postnatal pulmonary hypoplasia in CDH patients concluded that inability to achieve a pCO2 in the physiologic range (~60 mmHg) with mechanical hyperventilation predicted treatment futility [5,6]. In contrast, limitation of oxygenation because of the decreased pulmonary vascular bed in CDH cannot be reliably assessed because of superimposed reversible pulmonary hypertension. Preductal oxygen measurement best reflects oxygenation capacity in infants with CDH [7]. In clinical practice, transcutaneous preductal oxygen saturation (preductalO2Sat) is monitored in the right hand and preductalO2Sat of ≥85% is deemed acceptable [8,9].

In the past, hyperventilation and alkalinization were considered standard management strategies for neonatal CDH, and many centers developed ventilation and oxygenation criteria to predict treatment futility in CDH patients. The utility of these variables remains unclear in the current era of gentle ventilation. When making decisions regarding the use of aggressive medical support, many parents expecting an infant with a CDH want to wait and see how the infant’s lung will “work after birth”. The goal of our study was to evaluate the utility of admission pCO2 and preductalO2Sat to determine survival in

Abbreviations: CDH, congenital diaphragmatic hernia; pCO2, arterial partial pressure of carbon dioxide; preductalO2Sat, preductal oxygen saturation; ECMO, extra corporeal membrane oxygenation; NICU, neonatal intensive care unit.

☆ Conflict of Interest: All authors have no conflict of interest relevant to this article to disclose.
☆☆ Funding: No external funding.

* Corresponding author at: Suite CCC-410, Medical College of Wisconsin, 8701 Watertown Plank Road, Milwaukee, WI 53226. Tel.: +1 414 266 6719; fax: +1 414 266 6979.
E-mail address: mbasir@mcw.edu (M.A. Basir).
1 Cosenior authors.
neonatal CDH using contemporary neonatal ventilator strategies. We also explored the association of admission pCO₂ and preductalO₂Sat with markers of disease severity, including length of initial hospitalization, need for tracheostomy, home oxygen, and home tube feeding.

1. Materials and methods

1.1. Study type and setting

This is an Institutional Review Board-approved retrospective case series of all newborns admitted with a diagnosis of CDH to the neonatal intensive care unit (NICU) at Children’s Hospital of Wisconsin between January 1995 and December 2006. A tertiary academic hospital with an active obstetrical service is physically connected to the Children’s Hospital; births at this tertiary academic hospital are considered ‘inborn’ as ambulance or air transport is not required. Newborns admitted with a CDH were identified from a database maintained by the Division of Neonatology.

1.2. Data collection

Data abstracted from the medical records include: inborn status, prenatal diagnosis, gestational age at birth, birth weight, gender, Apgar scores, associated congenital anomalies, blood gas and ventilator data for the first 48 hours, use of ECMO, surgery information, survival and length of initial hospitalization. Blood gas, oxygen saturation and mechanical ventilation data were not collected for this study during ECMO. Information indicating status at discharge was also collected, including: need for tracheostomy, need for home ventilator, home supplemental oxygen, home tube feedings and home diuretic use. To assess post discharge mortality, the Wisconsin Death Registry was searched for all of the study subjects discharged alive from the NICU.

1.3. Clinical management

During the study period, hyperventilation was abandoned and permissive hypercapnia to prevent barotrauma was practiced at the study institution. Based on these experiences, the Divisions of Neonatology and Pediatric Surgery have developed management guidelines for neonates with CDH to assist with patient-centered and family-centered care. In the absence of significant respiratory distress or acidosis, permissive hypercapnia with pCO₂ ≤ 65 mmHg and preductalO₂Sat of ≥85%, are deemed acceptable. Conventional mechanical ventilation with moderate settings is generally used for respiratory support. Indications for the use of high-frequency oscillation included need for PIP > 25 cm H₂O, persistent pCO₂ - 65 mmHg, persistent preductalO₂Sat of <85%, need for inhaled nitric oxide, or persistent respiratory distress. Usually in our NICU, in an infant who is hypoxic on admission a chest x-ray is performed on admission and corrective interventions taken prior to obtaining the initial blood gas. For inborn CDH patients, the time lag between birth and first blood gas is usually at least 45 minutes. Outborn CDH patients are transferred within hours of birth by our transport team. Surfactant is used only in premature infants with radiologic evidence of respiratory distress syndrome. Muscle relaxants are used if preductalO₂Sat remains low. Decisions regarding ECMO are made on an individualized basis using internationally recognized criteria.

1.4. Statistical methods

Data were analyzed using STATA 11. Data were reported as mean ± standard deviation for continuous variables and median with interquartile ranges for variables with significant outliers. Total count and percent were reported for categorical variables. Chi-square test was performed for categorical variables and Mann-Whitney test or Student’s t test performed for continuous variables. Correlations between predictor and outcome variables were determined using univariate or multivariate regression and ROC curves.

2. Results

2.1. Cohort survival

Table 1 shows the characteristics of the study cohort. During the study period, 119 patients with CDH were admitted to the NICU and 88 (74%) survived to discharge. The Wisconsin Death Registry query and review of hospital records revealed death of one study patient after discharge. Table 2 shows characteristics associated with mortality. Infants with an associated major anomaly (n = 17) had the lowest survival (41%). Exclusion of patients with associated major anomalies increased the cohort survival to 79%. Patients with left CDH and no other major anomaly (n = 93) had 81% survival.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Survived</th>
<th>Died</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall, n (%)</td>
<td>119</td>
<td>88 (74)</td>
<td>31 (26)</td>
<td></td>
</tr>
<tr>
<td>Gestational Age, wk, mean ± SD</td>
<td>119</td>
<td>38 ± 2</td>
<td>37 ± 2</td>
<td>0.02</td>
</tr>
<tr>
<td>Birth Weight, g, mean ± SD</td>
<td>119</td>
<td>3180 ± 63</td>
<td>2636 ± 61</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Apgar Score 1, mean ± SD</td>
<td>119</td>
<td>5 ± 2</td>
<td>3 ± 2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Apgar Score 5, mean ± SD</td>
<td>119</td>
<td>7 ± 2</td>
<td>5 ± 2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Inborn, n (%)</td>
<td>Yes</td>
<td>55</td>
<td>34 (62)</td>
<td>21 (38)</td>
</tr>
<tr>
<td>No</td>
<td>64</td>
<td>54 (84)</td>
<td>10 (16)</td>
<td></td>
</tr>
<tr>
<td>Prenatal Diagnosis, n (%)</td>
<td>Yes</td>
<td>59</td>
<td>37 (63)</td>
<td>22 (37)</td>
</tr>
<tr>
<td>No</td>
<td>60</td>
<td>51 (85)</td>
<td>9 (15)</td>
<td></td>
</tr>
<tr>
<td>Associated Anomalies, n (%)</td>
<td>Yes</td>
<td>17</td>
<td>7 (41)</td>
<td>10 (59)</td>
</tr>
<tr>
<td>No</td>
<td>102</td>
<td>81 (79)</td>
<td>21 (21)</td>
<td></td>
</tr>
<tr>
<td>Left CDH, n (%)</td>
<td>Yes</td>
<td>106</td>
<td>81 (76)</td>
<td>25 (24)</td>
</tr>
<tr>
<td>No</td>
<td>11</td>
<td>6 (55)</td>
<td>5 (45)</td>
<td></td>
</tr>
<tr>
<td>pCO₂ ≥ 80 mmHg</td>
<td>Yes</td>
<td>24</td>
<td>7 (29)</td>
<td>17 (71)</td>
</tr>
<tr>
<td>No</td>
<td>94</td>
<td>80 (85)</td>
<td>14 (15)</td>
<td></td>
</tr>
<tr>
<td>PreductalO₂Sat &lt; 85%</td>
<td>Yes</td>
<td>17</td>
<td>3 (18)</td>
<td>14 (82)</td>
</tr>
<tr>
<td>No</td>
<td>81</td>
<td>67 (83)</td>
<td>14 (17)</td>
<td></td>
</tr>
</tbody>
</table>

* Logistic regression with outcome died or survived.
Table 3

Admission Blood Gas and Mechanical Ventilation in CDH Patients, N = 119.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Survivors, N = 88</th>
<th>NonSurvivors, N = 31</th>
<th>p (All NonSurvivors vs. All Survivors)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Outborn n = 54</td>
<td>Inborn n = 34</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAP, mm H2O</td>
<td>11 ± 3</td>
<td>11 ± 3</td>
<td>ns&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>HFOV, n (%)</td>
<td>4 (7)</td>
<td>3 (8)</td>
<td>ns&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>pH</td>
<td>7.34 ± 0.15</td>
<td>7.23 ± 0.12</td>
<td>&lt;0.001&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>PCO₂, mmHg</td>
<td>45 ± 20</td>
<td>60 ± 20</td>
<td>&lt;0.01&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Po₂, mmHg</td>
<td>100 ± 94</td>
<td>100 ± 87</td>
<td>ns&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Preductal Saturation, %</td>
<td>97 ± 5</td>
<td>96 ± 5</td>
<td>ns&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Postductal Saturation, %</td>
<td>94 ± 9</td>
<td>91 ± 9</td>
<td>ns&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAP, mm H2O</td>
<td>17 ± 6</td>
<td>15 ± 6</td>
<td>ns&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>HFOV, n (%)</td>
<td>7 (70)</td>
<td>9 (43)</td>
<td>ns&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>pH</td>
<td>7.02 ± 0.2</td>
<td>7.04 ± 0.3</td>
<td>&lt;0.001&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>PCO₂, mmHg</td>
<td>88 ± 34</td>
<td>84 ± 49</td>
<td>&lt;0.001&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Po₂, mmHg</td>
<td>48 ± 19</td>
<td>62 ± 51</td>
<td>0.015&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Preductal Saturation, %</td>
<td>83 ± 20</td>
<td>80 ± 15</td>
<td>&lt;0.001&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Postductal Saturation, %</td>
<td>74 ± 18</td>
<td>76 ± 14</td>
<td>&lt;0.001&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Mean ± SD are shown unless otherwise stated.

<sup>a</sup> ns, not significant [p > 0.05].

<sup>b</sup> Two sample proportion comparison.

<sup>c</sup> Two sample t test.

<sup>d</sup> Mann–Whitney test.

2.2. Inborn vs. outborn

Sixty-four (54%) patients were outborn and of these 84% survived to discharge. Outborn CDH patients had a lower rate of prenatal diagnosis (16% vs. 89%, p = 0.006), fewer associated anomalies (6% vs. 24%, p = 0.005) and better survival to discharge (84% vs. 62%, p = 0.006). Outborn infants were more mature (39 wk ± 2 vs. 37 wk ± 2, p = 0.001) and larger (3245 g ± 54 vs. 2902 g ± 72, p = 0.001) at birth. On admission, outborn survivors had lower PCO₂ than inborn survivors; however, both outborn and inborn patients who ultimately died had equally nonphysiologic PCO₂ and preductal O₂Sat on admission to our NICU (Table 3).

2.3. Admission mode of ventilation, PCO₂ and preductal O₂Sat

In 23 (19%) patients mechanical ventilation was initiated with a high frequency oscillatory ventilator (HFOV). Survival was significantly lower in neonates assessed to require HFOV on admission (30% vs. 84%, p ≤ 0.001). There was no difference between survivors based on admission use of conventional ventilation or HFOV, in PCO₂ (49 ± 20 vs. 52 ± 17, p = 0.72) or preductal O2Sat (97 ± 4 vs. 92 ± 11, p = 0.32). Similar comparison between the groups of nonsurvivors was also not different, PCO₂ (93 ± 51 vs. 81 ± 48, p = 0.59) and preductal O₂Sat (81 ± 15 vs. 83 ± 16, p = 0.74).

2.4. Admission PCO₂, preductal O₂Sat and survival

Survivors required less mechanical ventilator support and had more physiologically normal blood gas values and oxygen saturation than nonsurvivors (Table 3). The mean admission PCO₂ was higher among nonsurvivors than the survivors, 86 ± 48 vs. 49 ± 20, p ≤ 0.001; however, after 6 hours this difference was less significant, Fig. 1. Among nonsurvivors, the observed fall within 6 hours of admission in PCO₂, 86 ± 44 to 48 ± 14, was similar among outborn (89 ± 33 to 46 ± 13) and inborn patients (84 ± 49 to 49 ± 20). The area under the ROC curve for admission PCO₂ to predict death or survival was 0.74. The positive predictive value (PPV) of admission PCO₂ ≥ 80 mmHg to predict mortality was 0.71.

Ninety-seven patients had preductal O₂Sat monitoring documented in the first hour after admission. The mean preductal O₂Sat was significantly lower in nonsurvivors than survivors, Fig. 2. The largest difference in mean preductal O₂Sat between survivors and nonsurvivors was in the first hour, 97 ± 5 vs. 81 ± 17, p ≤ 0.001. The area under the ROC curve for preductal O₂Sat to predict death or survival was 0.85. The PPV of admission preductal O₂Sat < 85% to predict mortality was 0.82.

Variables associated with death in univariate analysis (Table 2) were analyzed using multivariate logistic regression. In a model including inborn status, Apgar score at 5 minutes, associated anomalies, admission PCO₂ and first hour preductal O₂Sat, only admission PCO₂ ≥ 80 mmHg and first hour preductal O₂Sat < 85% were significantly associated with death or survival. The R² of this model was 0.36. Ninety-seven patients had both admission PCO₂ and first hour preductal O₂Sat available; of these subjects, 11 had both PCO₂ ≥ 80 mmHg and preductal O₂Sat < 85% and only one survived (9%); giving sensitivity of 91%, specificity of 99% and a PPV of 0.92.

2.5. Admission PCO₂, preductal O₂Sat and survival with ECMO

Of the 119 study patients, 32 (27%) received ECMO support and of these 19 (59%) survived. Among those receiving ECMO, 10 patients had admission PCO₂ ≥ 80 mmHg and of these 4 survived; 6 patients had first hour preductal O₂Sat < 85% and 1 survived; 3 patients had admission PCO₂ ≥ 80 mmHg and first hour PreO₂Sat < 85% and of these none survived.

Eighteen patients died without ECMO. The patients who died without receiving ECMO support were less mature and smaller. Death was more prolonged in patients who received ECMO support than those who did not receive ECMO, with median survival days of 24 vs. 1, p = 0.008.

2.6. Admission PCO₂, preductal O₂Sat and surgical repair

Surgical repair was not attempted in 22 (71%) nonsurvivors and 9 subjects who were repaired had died. Admission PCO₂ ≥ 80 mmHg was associated with longer duration from admission to surgery (median days of 4 vs. 9, p < 0.001); first hour preductal O₂Sat showed...
a similar trend. The association of higher admission pCO2 with the use of a patch for repair did not reach statistical significance (p = 0.06).

2.7. Admission pCO2, preductalO2Sat, length of stay and home health care needs

Among survivors, admission pCO2 ≥ 80 mmHg was associated with higher need for home oxygen therapy (14% vs. 71%, p = 0.001), discharge with diuretics (8% vs. 43%, p = 0.007), requirement for nasogastric or gastrostomy feedings at discharge (41% vs. 100%, p = 0.001) and longer length of stay (48 ± 52 vs. 98 ± 54 days, p = 0.01). Only 3 patients who had initial preductalO2Sat < 85% survived and one of these three patients went home on supplemental oxygen and tube feedings.

3. Discussion

In this retrospective case series of 119 CDH patients admitted to a tertiary NICU and managed with contemporary ventilation techniques, we found that initial admission pCO2 and preductalO2Sat during the first hour are important for prognostication of survival. However, within hours of admission, the predictive value of these parameters lost their significance. These data are consistent with the concept that the initial arterial pCO2 and first hour preductalO2Sat remain indicative of the severity of pulmonary hypoplasia present during gentle ventilation strategy. The reasons for the loss of prognostic significance of gas exchange measures within the first few hours of NICU admission are unclear. We speculate that this may be related to the availability of interventions such as HFOV, inhaled nitric oxide, and inotropic support, which may improve pCO2 and preductalO2Sat without altering the course of pulmonary hypoplasia or changing the infant’s survival.

Importantly, these data indicate that initial pCO2 and first hour preductalO2Sat have predictive value irrespective of outborn or inborn status. We initially contemplated separating these groups because findings from this study and others reveal significant overall differences between outborn and inborn neonates in the rates of prenatal diagnosis, incidence of associated anomalies, birth weight and gestational age [11,12]. However, the levels of pCO2 and preductalO2Sat on admission to the tertiary NICU were not different in nonsurvivors from both inborn and outborn groups. In addition, these two variables were the only ones that remained significant in multivariate regression. We therefore, felt it was reasonable to combine these two groups. This lack of difference in admission pCO2 and preductalO2Sat between outborn and inborn neonates may partially reflect their differential access to neonatal expertise and advanced technological resources in community-based birthing centers in comparison to contemporary NICUs in tertiary care children’s hospitals.

Other investigators have postulated that this differential access to medical care results in “hidden mortality” among outborn CDH patients with an apparent improved survival rate. Survival was higher for our outborn patients; however, the rates of prenatal diagnosis and incidence of associated anomalies were also lower in this patient population. Our study is not population based; hence we cannot draw conclusions in this regard. However in the current era of improved fetal imaging, higher risk CDH patients are more likely to be diagnosed prenatally resulting in either termination of pregnancy or delivery in a tertiary hospital. Despite having better survival and markers suggestive of less severe CDH, outborn patients were as likely as inborn patients to require ECMO support.

We found that a higher admission pCO2 was associated with longer time from admission to surgery, increased length of stay, increased need for home tube feeding and home oxygen. These discharge outcomes suggest a higher likelihood of morbidity in survivors with high admission pCO2 values. We speculate and are currently investigating the hypothesis that long-term developmental and functional outcomes of CDH survivors may also correlate with physiological data available at initial admission.

Almost four decades ago, hyperventilation was considered the standard of care for CDH patients requiring mechanical ventilation; investigators recognized that treatment in some patients was futile because of critical pulmonary hypoplasia, characterized by inadequate gas exchange [4,13]. At the time, some centers adopted criteria for foregoing further aggressive medical or surgical intervention if the best pCO2 achieved was >60 mmHg despite hyperventilation [5]. Subsequent studies revealed the detrimental effects of mechanical hyperventilation and the concept of gentle ventilation was embraced [8,14]. In the current era of gentle ventilation, postnatal ventilation and oxygenation criteria capable of determining critical pulmonary hypoplasia have not been well studied. Boloker et al. from New York Presbyterian Hospital and Columbia University, reported outcomes in 120 CDH patients managed with gentle ventilation [15]. The values and trends reported among survivors and nonsurvivors by Boloker et al of pCO2 in the first 36 hours, as well as normalization of the pCO2 within hours of tertiary NICU care, are consistent with our data.

Recently, Yoder et al. reported the utility of several postnatal markers to predict survival, using data from the Congenital Diaphragmatic Hernia Study Group for the first 24 hours after admission [10]. The 4434 patients included in their analysis represent postnatal treatment practices from multiple national and international NICUs. This study reported a PPV of 57% to predict mortality when the minimum pCO2 was ≥ 70 mmHg during the first 24 hours and PPV of 77% when the best preductalO2Sat was <85%. A PPV of 88% was reported when both parameters were met. We found similar predictive values utilizing information obtained within 1 hour of admission to our NICU. With permissive hypercapnia, many centers accept pCO2 of 65–70 mmHg. Therefore, for clinical relevance and to lower the likelihood of false positive determination of nonsurvival, we used 80 mmHg as the cutoff in our study. Given the reproducibly observed normalization of pCO2 and preductalO2Sat within hours of NICU admission for both survivors and nonsurvivors, we and others believe that assessment of CDH severity for use in prognostication is most valuable in the immediate postnatal period and can be easily obtained with arterial blood gas and preductalO2Sat monitoring [16]. This approach suggests that the prediction of survival outcome for neonatal CDH may be relatively independent of postnatal treatment.

The current study has limitations. Our study represents a single, retrospective institutional experience in an academic medical center.
We did not include initial blood gas or preductal O2Sat data obtained by referring institutions on outborn infants because the clinical management, including ventilation and laboratory draw, is known to vary considerably between referral centers. The concept of gentle ventilation is embraced at our institution; however, we do not mandate that all attending physicians use the same mode or intensity of mechanical ventilation. It is reassuring however, that the pCO2 in our patients is very similar to values published by institutions recognized nationally for their practice of permissive hypercapnia [15]. In addition, other changes in clinical practice during the study period may also influence our findings. The study model also does not allow for prediction of mortality with 100% certainty.

Despite these limitations, our observations are valuable in providing the clinician a rational approach of sharing the probability of these outcomes with the parents of a newborn infant with severe CDH. This study did not correlate prenatal prognostic indicators of CDH such as fetal lung head ratio [LHR], total lung volume estimates, or liver position with admission gas exchange and we recognize this as an area of opportunity. Currently, parents are routinely counseled when pregnancy is complicated by CDH and provided outcome information based on prenatal prognostic markers; a recent study of prenatal markers showed a survival of 38% when a composite of 10 of these markers was used [17]. Whether a combination of fetal indicators and initial physiological performance parameters upon arrival to a NICU provide more clarity in survival prognostication remains to be determined.

In conclusion, neonates with severe CDH require significant supportive measures, and despite technological and management advances, approximately one fourth of these infants do not survive and many of the survivors will have significant morbidity [18–21]. Evaluating the adequacy of gas exchange using admission pCO2 and preductal O2Sat monitoring may be useful in predicting survival outcome for both outborn and inborn neonates with CDH. Additionally, these physiologic data can potentially be combined with anatomic data to paint an increasingly granular picture of CDH severity. However, use of absolute values should be limited to center-specific data, as differences in initial strategies may result in different initial numbers. After optimization of therapy in the NICU, clinicians should expect normalization of pCO2, making this variable less helpful from a prognostic standpoint over time. This routinely available measurement on admission may also help to predict long-term morbidity among survivors.

References