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Protocolized Approach to the Management of Congenital Diaphragmatic Hernia: Benefits of Reducing Variability in Care

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Abstract

Purpose—Variable approaches to the care of infants with congenital diaphragmatic hernia (CDH) by multiple providers may contribute to inconsistent care. Our institution developed a comprehensive evidence-based protocol to standardize the management of CDH infants. This report reviews patient outcomes prior to and after implementation of the protocol.

Methods—Retrospective chart review of CDH infants managed with individualized care (Pre-protocol group, January 1997–December 2001, n=22) or on the protocol (Protocol group, January 2002–July 2009, n=47). Survival and other categorical variables were compared by chi square analysis and continuous variables were compared using one-sided ANOVA analysis with significance defined as $p < 0.05$.

Results—Survival to discharge was significantly greater in the Protocol group (40/47 (85%)) than the Pre-protocol group (12/22 (52%)) $p = .006$ although mean gestational age, mean birth weight, and expected survival were not statistically different between the two groups. The use of supportive therapies, including high frequency jet ventilation, inhaled nitric oxide, and extracorporeal life support was similar between groups as well.

Conclusions—Since implementation of a management protocol for infants with CDH, survival has improved significantly compared with expected survival and pre-protocol controls. Reduction in the variability of care through use of an evidence-based protocol use may improve the survival of CDH infants.

Keywords

Congenital diaphragmatic hernia; variability; evidence-based care guidelines; protocolized care

Introduction

Infants with congenital diaphragmatic hernia (CDH) are among the most complex and perplexing patients that neonatologists and pediatric surgeons must manage. The high acuity and intricate medical care of these infants contributes to their high mortality and morbidity.^{1–7} With the development of gentle ventilation strategies and accumulation of experience at higher-volume centers, survival rates have improved over the last two decades.

Still, survival rates reported in the literature have ranged from 50–90% overall, with many “benchmark” centers reporting survival rates of 78–95%.^{3,5,6}

Variability in physician decision making is common, in part because of deficiencies in their knowledge base, but also due to the difference in physicians’ approaches to clinical problem solving.⁷ Although current medical therapies may improve the care of CDH infants, application of these therapies often varies greatly between practitioners, even within the same institution.⁶ For complex medical conditions such as CDH, variability in care makes it difficult to assess the effects of specific medical interventions. To standardize and simplify care, several centers have reported using detailed care protocols for infants with CDH.^{8–11} However, most of these reports compare post-protocol outcomes to historical controls managed prior to the adoption of the gentle ventilation strategies. To our knowledge, only one report compares the outcomes of similar groups of CDH infants after implementation of a care protocol.⁹ Therefore, it is difficult to assess the impact of implementing an evidence-based protocol rather than the effect of a specific medical intervention.

To improve and standardize care of CDH infants at our institution, a multidisciplinary team developed a comprehensive medical care protocol based on a literature review of current best practices from published reports CDH care.⁶ The current report describes our management protocol and reviews the outcomes of CDH infants at our institution prior to and after the implementation this protocol.

Materials and Methods

Study Design

We performed a retrospective chart review of CDH infants managed at our institution from 1997–2006 using a prospectively designed data collection form. The charts of all infants with a diagnosis of CDH by ICD-9 code were reviewed. Infants with isolated CDH, gestational age greater than 34 weeks, and CDH diagnosed within the first 24 hours of life were included in the study. Those infants managed prior to the implementation of our CDH management protocol (January 1997–December 2001) received individualized care (Pre-protocol group). All infants born with CDH from January 2002–July 2009 were managed using the CDH protocol (Protocol group). This study was approved by the Duke University Medical Center Institutional Review Board.

Expected survival was calculated using the logistic regression equation previously published by the CDH Study Group.¹² We compared demographic data including gestational age and birth weight between the two groups using a one-sided ANOVA analysis and by calculating standard deviation as a measure of dispersion. We compared categorical variables, including survival, using chi square analysis. Data was considered significant at $p < 0.05$.

Protocol for the Management of Infants with CDH

After extensive literature review and discussion by a multidisciplinary team of pediatric surgeons, neonatologists, pediatric intensivists and respiratory therapists, a management protocol was developed and implemented in 2002. The goals of the management protocol were: 1) to standardize the care of these infants, 2) to minimize lung injury, and 3) to guide early consideration of extracorporeal life support (ECLS). Antenatal management after diagnosis of CDH by ultrasound included family meetings with neonatologists and pediatric surgeons as well as fetal echocardiography to assess cardiac anatomy. Antenatal steroids were given only in cases of threatened delivery before 34 weeks. At delivery, infants were immediately intubated and placed on early ventilator support, with peak inspiratory pressures (PIP) kept below 24 mmHg.

In order to facilitate communication between care providers in regards to the physiologic status of each infant, the protocol divided the degree of medical supportive therapies into three categories depending on the level of cardiac and pulmonary support required: safe zone, caution zone, and hazard zone (Fig 1). Safe zone therapies were those that minimize barotraumas and other iatrogenic injury. Caution and hazard zone levels of support represented incremental escalations in therapy. “Ideal” patients were defined as infants who could maintain a pre- and post-ductal O₂ saturations > 95% on safe zone ventilator and vascular support.

To minimize barotrauma, we developed strict respiratory care guidelines. All infants who required PIP > 26 mm Hg and/or mean airway pressures (MAP) > 12 mm Hg to achieve PaCO₂ < 65 mmHg were switched early from conventional ventilation to either high frequency jet ventilation (HFJV) or high frequency oscillating ventilation (HFOV). If an infant required caution zone levels of support to maintain the ideal patient parameters, consideration of weaning ventilatory support to achieve “non-ideal acceptable” parameters was required with the goal of weaning the infant to a “safe zone” level of support. The non-ideal acceptable parameters included PaCO₂ up to 65 mmHg and PaO₂ as low as 30 mmHg as long as preductal O₂ saturations are > 85% and a pH > 7.25 without worsening acidosis. Infants who required hazard zone therapies for more than a few hours to maintain ideal parameters were to be weaned to caution or safe zone therapies to reach non-ideal acceptable parameters.

If an infant required caution zone therapies greater than 12–24 hours to maintain non-ideal acceptable parameters, pediatric surgery, ECLS team intensivist, and neonatology staff would jointly discuss use of ECLS. ECLS was considered in all cases in which hazard zone therapies could not be weaned within 12–24 hours. Indications for ECLS included inability to maintain a postductal PaO₂ of 30 mmHg, a preductal O₂ saturation of 85%, or a postductal pH of > 7.25.

Results

We identified 69 infants with CDH at our institution from 1997–2009 who met inclusion criteria for this study (Table 1). We divided infants into a Pre-protocol group (n=22, 1997–2001) and Protocol group (n=47, 2002–2009). The two groups had no significant differences in mean birth weight (Pre-protocol 3022 ± 694 g, Protocol 33243 ± 468g, p=0.12) or gestational age (Pre-protocol 38.6 ± 1.2, Protocol 38.6 ± 1.2, p=0.92). Both groups had similar proportion of inborn infants (Pre-protocol 13/22, Protocol 29/47, p=0.65). Although the expected survival (calculated based on the CDH Study Group regression equation)¹² was slightly higher for the Protocol group, this difference was non-significant. However, actual survival to discharge was significantly higher for the Protocol group (40/47, 85%) than for the Pre-protocol group (12/22, 55%, p=0.006).

When we examined the use of specific supportive therapies in the Pre-protocol and Protocol groups, we found no difference in the number of infants managed with high frequency ventilation (HFV), inhaled NO (iNO) or ECLS (Table 2). Although the overall rate for use of HFV did not vary between Pre-protocol and Protocol groups, there was a greater rate of high frequency jet ventilation compared to high oscillating ventilation in the Protocol group. Also, although survival after ECLS to surgical repair of CDH was similar between the groups (74% versus 81%, p=0.27), survival to discharge demonstrated a trend towards improved survival for the Protocol group (6/11, 55%) compared with the Pre-protocol group (0/4, 0%, p=0.056). When we excluded infants requiring ECLS from the analysis, we found that survival to discharge remained significantly higher for the Protocol group (33/35, 94%) than for the Pre-protocol group (12/18, 67%, p=0.008).

Discussion

Since the development and implementation of an evidence-based care protocol for managing CDH infants at our institution, we have seen a significant improvement in survival to discharge (from 55% to 85%) compared to infants managed without a protocol, despite similar expected survival rates between these two groups. We also noted a trend towards improved survival among CDH infants placed on ECLS after the implementation of our protocol, although the frequency for the use of ECLS was similar between the cohorts.

Our findings suggest that implementation of a standardized care protocol may contribute to improved survival for infants with CDH. However, exactly which aspect of the protocol may have had the greatest impact on survival remains unclear. Most recent studies of CDH management agree that gentle ventilation strategies will result in improved survival, making possible the 79–95% survival rates seen at benchmark centers today.^{3–6, 13–15} However, the specific ventilation strategies used among centers vary widely.⁶ Because of this variation in practice, it is unlikely that the improvement in survival with use of a care protocol in our study can be explained by use of any single ventilation strategy alone. Furthermore, our control group had similar patient characteristics to the Protocol group, with both groups receiving similar care based on gentle ventilation. Finally, the frequency of other specific supportive strategies in our study, such as HFV, iNO, and ECLS did not change significantly from the Pre-protocol to Protocol group, although specific weaning parameters and duration of therapy may have differed.

The lower rate of HFOV use in the Protocol group reflects the use of HFJV as primary mode of HFV for infants failing conventional ventilation in that group compared with equal use of HFJV and HFOV in the Pre-protocol group. Although this change may have impacted survival in the Protocol group, the overall use of HFJV was similar between the two groups (41% versus 55%, $p=0.26$). There are theoretical advantages related to enhanced cardiac output for the jet ventilator compared with the oscillator ventilator,^{16–18} but specific high frequency ventilator strategies for CDH infants have not been compared in human trials or in animal models of CDH.

Several authors have found that the implementation of detailed, evidence-based protocols can improve outcomes in intensive care settings where the complexity of patient management can lead to significant variability among providers.^{19–21} Guidelines and protocols with sufficient detail to support clinical decision-making have been shown to reduce variations in care resulting in better patient outcomes for the management of hyperglycemia, ARDS, sepsis, and ventilator weaning.^{23–28} The favorable impact of our protocol on the survival of CDH infants may result in large part simply from the reduction in the variability of care among providers rather than any one specific therapy, as has been noted in other clinical settings.

One major advantage of a care protocol is the ability to facilitate communication among care providers in regards to the physiologic status of a complex patient. Our care protocol was designed to simplify the management of CDH infants by dividing therapies into three “zones” of support which could be easily understood and discussed by multiple care providers. The protocol also emphasized the importance of reducing barotrauma to protect the lung and monitoring cardiac function as crucial in decisions to move toward early consideration of ECLS. Additionally, the process of convening a multidisciplinary team to review existing CDH literature, discuss best practices, and develop management guidelines may in itself have contributed to improved care. Our findings support Logan’s assertion that the development and implementation of detailed treatment guidelines may be as important as any single support strategy in improving the survival of CDH infants.⁶

Our study has several limitations. The retrospective design of the study limits the validity of comparing outcomes between treatment epochs, and the small sample size limits its generalizability. Also, there is significant potential for selection bias. Although the expected survival for the Pre-protocol group was not significantly different than the Protocol group (58% compared with 70%, $p=0.35$), the discrepancy could indicate that the infants in the Pre-protocol group were more severely affected. We re-analyzed the data excluding the infants requiring ECLS from both groups in case the high mortality after ECLS in the Pre-protocol group reflected a sicker group of patients in this cohort. However, we found that survival to discharge in the Protocol group still remained significantly higher than in the Pre-protocol group (94% compared with 67%, $p=0.008$) when these infants were excluded. Also, by including CDH infants treated 1997–2002 as our individualized care controls, we sought to identify a Pre-protocol control group with similar patient characteristics to the Protocol group. Both groups received similar care based on evidence-based strategies of gentle ventilation.

Since, the expected survival rates for both the Pre-protocol and Protocol groups was not statistically different, we attribute improvements in survival to the use of a protocol, rather than a difference in the severity of CDH between the two groups. Although the CDH study group expected survival model has been criticized for underestimating survival with modern therapeutic strategies, this model does allow for comparison between our two study cohorts.¹¹ Even if this model underestimates survival, both groups should be equally affected. Other predictors of outcome, including the modified McGoon Index (MMI) and OI ($\text{MAP}/\text{PaO}_2 \times 100$) may be more accurate in predicting outcomes,⁶ but could not be used for our cohort comparison due to the retrospective nature of the review.

We cannot exclude the possibility that other factors not examined in this study affected survival. For example, although there were no major changes in physician or other staffing patterns and training at our institution from 1997–2009, these variables were not comprehensively evaluated. We also were unable to isolate the impact of accumulation of experience in managing CDH infants over time by individual providers. One additional limitation of our study is that it represents a single institution experience, limiting the generalizability of the study.

In summary, we have shown a significant improvement in survival of CDH infants after implementation of an evidence-based care protocol at our institution. Not only did survival improve with use of a care protocol, but we achieved a survival rate that is within the range of other “benchmark” centers. Our findings provide further evidence of the efficacy of management protocols for CDH infants, although prospectively collected data from multiple centers is required for further validation of this approach. In the modern era where CDH care remains variable between institutions, protocolized care may allow for careful analysis of the effects of specific medical therapies.

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Figure 1.
 Congenital Diaphragmatic Hernia Management Protocol

Table 1

Outcomes Prior to and After Implementation of Evidence-Based CDH Protocol

	Pre-Protocol 1997–2001, n=22	Post-Protocol 2002–2009, n=47	p-value
Inborn	13 (59%)	29 (61%)	0.65
Mean Birth Weight	3022 (+/- 694) g	3243 (+/- 468) g	0.12
Mean Gestational Age	38.6 (+/- 1.18)	38.6 (+/- 1.19) wks	0.98
Expected Survival*	57.9%	69.5%	0.35
Survival to Discharge	12 (55%)	40 (85%)	0.006

Birth weight and gestational age reported as mean +/- SD.

* Expected survival based on CDH study group survival equation

Table 2

Supportive Therapies Prior to and After Implementation of Evidence-Based CDH Protocol

	Pre-Protocol 1997–2001, n=22	Post-Protocol 2002–2009, n=47	p-value
High Frequency Ventilation	14 (64%)	29 (56%)	0.87
High Frequency Jet Ventilation	9 (41%)	26 (55%)	0.26
High Frequency Oscillating Ventilation	7 (50%)	3 (8%)	0.005
Inhaled NO	6 (27%)	19 (40%)	0.89
ECLS	4 (18%)	11 (23%)	0.62
Survival to CDH Repair after ECLS	3 (74%)	9 (82%)	0.27
Survival to Discharge after ECLS	0/4 (0%)	6/11 (55%)	0.056

Frequency for use of supportive therapies for infants with congenital diaphragmatic hernia in Pre-protocol and Protocol groups. NO is nitric oxide, ECLS is extracorporeal life support.