Fundamentals of CDH Care

David Kays, MD
Professor of Surgery
Johns Hopkins School of Medicine
Director of Congenital Diaphragmatic Hernia Program, Director of Extra Corporeal Life Support Program
Johns Hopkins All Children’s Hospital, St. Petersburg, FL

The speaker has signed a disclosure form and indicated he has no significant financial interest or relationship with the companies or the manufacturer(s) of any commercial product and/or service that will be discussed as part of this presentation.

Session Summary
Optimizing survival in CDH infants requires neither finding a new drug nor developing a new mode of ventilation, but rather lies in understanding CDH physiology and adhering to the fundamentals of CDH care. This talk, based on CDH survival rates thought unobtainable, will outline those fundamentals.

Session Objectives
At the conclusion of this activity, participants will be able to:
▪ describe the anatomic and physiologic markers that relate to CDH severity;
▪ discuss the role of strict lung protective ventilation in CDH;
▪ state the importance of CDH repair in CDH survival outcomes.

References


Fundamentals of CDH Care: Part 1

Why should you listen to me?

- Cared for > 325 CDH
- No patients turned away
- Overall Survival (everyone) = 80%
- Survival of "isolated" CDH now > 95%
- ALL pts d/c breathing on their own.
- No patients d/c with tracheostomy. None

CDH is Important (1)

CDH affects 1 in every 3000 live births

In 2014 in the USA, there were 3,988,076 births
- 800 with gastroschisis and fewer than 100 died (*estimate)
- 500 will develop Wilms tumor, and fewer than 100 died or will die
- > 1300 fetuses will have CDH.

650 or more will die from CDH, from termination or during treatment

CDH is Important (2)

CDH Patients are Severity Outliers:

- Small lungs and pulmonary hypertension
- Under-developed hearts
- Are at risk of hypoxic-ischemic brain injury
- Need exacting critical care

Advancing the care of CDH babies improves the care of all neonates

CDH is a Frequently Lethal Defect

Pulmonary Hypoplasia

Pulmonary Hypertension
- Fixed component due to small lungs
- Reactive component due to CDH physiology
  - time course
What is the Current CDH Survival?

54% Survival (2014) (Canadian Population Study)  
Baylayla et al, J Mat-Fetal & Neo Medicine 2014

68% Survival (2009): CDH Study Group  
Seetharamaiah et al, J Ped Surgery, 2009

CDH is a Spectrum

Can define by Herniated Viscera
Left: Liver-down (least severe)  
Right: more severe (on average)  
Left: Liver-Up (most severe)

Can define by Lung Size: Lung to head ratio (LHR). 3-D Lung volumes  
LHR > 1.4 less severe  
LHR 1.3 – 1.4 more severe  
LHR < 1.3 most severe

Can define by physiology at birth and soon after  
Apgar scores at 1 and 5 minutes  
Birth weight  
CDH Study Group predicted survival (birth weight and 5 minute Apgar)  
Ninetytools.org  
Blood gas values at 1 hour of life (pH, PCO2, PO2)

L CDH, Liver-down  
(Least severe, stomach down)

Prognosis is excellent

L CDH, Liver Down  
(Stomach Up)

L CDH: Most Severe  
(Liver Up)

- Extremely Severe CDH  
- Large liver-Up  
- R lung is also very small, poorly inflated  
- ABG's are dismal (remember this child)  
- First ABG: 6.64 / >130 / 15
CDH is a Spectrum

- Lung Size: Lung to head ratio (LHR).
  - LHR > 1.4: less severe
  - LHR 1.0–1.4: more severe
  - LHR < 1.0: most severe

- Physiology at birth and soon after:
  - Apgar scores at 1 and 5 minutes
  - Birth weight
  - Blood gas values at 1 hour of life (pH, PCO2, PO2)

**Defining CDH Severity by Physiology**

|                      | Overall (n=198) | Died (p<0.01) | Survived (p<0.05) | R  
|----------------------|-----------------|---------------|-------------------|-----
| LHR                  | 1.5 (0.5, 4.5)  | 3.0 (0.5, 2.4) | 1.6 (0.5, 4.3)    | .001|

**CDH Severity by Anatomic Grading**

- Most severe anatomic subset
- Worst pulmonary hypoplasia
- 45% Survival 2010 Meta-analysis survival
- 45% Survival 2012 Top CDH Children's Hospital Publication

- Major Associated Anomalies (10% of total)
  - Cardiac: Uni-ventricular heart (poor prognosis)
  - Fetal echo
  - Genetic: Major chromosome and Syndromes (poor prognosis)
  - Amniocentesis
  - CNS (poor prognosis)

- CDH Severity
  - Volume of herniated viscera
  - Lung size
  - Physiology at birth

**Most CDH are diagnosed prenatally:**

- What do we tell expectant parents?
  - (1) Major Associated Anomalies (10% of total):
    - Cardiac: Uni-ventricular heart (poor prognosis)
    - Fetal echo
    - Genetic: Major chromosome and Syndromes (poor prognosis)
    - Amniocentesis
    - CNS (poor prognosis)

- (2) CDH Severity
  - Volume of herniated viscera
  - Lung size
  - Physiology at birth
**Fundamentals of CDH Care**

23 Years of CDH care and Research (320 CDH patients)

5 major lessons learned
- Lungs (ventilation must be lung protective. Really)
- Repair (required)
- ECMO (Not all ECMO is the same)
- Risk stratification to define care
- Believe

**CDH: Treatment of Surgery**

Detrimental Effects of Standard Medical Therapy in Congenital Diaphragmatic Hernia

- Hypothesis:
- Hyperventilation/alkalosis is harmful to CDH patients
- Elimination of this therapy will result in improved survival
- Prospective change in therapy in August, 1992

Kays, Langham, Ledbetter, and Talbott

**Ventilation/Oxygenation Goals**

- Goal PaCO2: 40 - 60. Will Tolerate: 60 - 70
- Goal PaO2: 80 – 110 Will Tolerate: Much lower
  - IF:
    - Pre-ductal sats> 85% and stable or rising
    - Perfusion is satisfactory
    - Serum lactate is normal and not rising
- Goal pH> 7.20 Treat with NaHCO3
- Keep PIP minimal. Preserve lung parenchyma


**Mean PIP over 120 hours**

![Mean PIP over 120 hours graph](image)

Mean +/- SEM
p<0.05 at all time points
p=0.0001 Time*Era effect


**Survival Curve by Era, All Patients**

![Survival Curve by Era graph](image)

Survival Graph p<0.0001

Mean PIP over 120 hours

Mean +/- SEM

p<0.05 at all time points

p=0.00001

Time*Era effect

PaCO2 over 120 hours by Era

Mean +/- SEM

p< 0.05 at all time points except T= 12 and 108 hours

p<0.05 Time*Era effect

Arterial pH over 120 hours

Mean +/- SEM

p< 0.05 at all time points except t=12 hours

p< 0.0003 Time*Era effect

Survival Curve by Era, All Patients

Survival Graph p=0.0001

CDH Treatment Fundamental #1

Must eliminate any iatrogenic lung injury:

The number of CDH patients that survive is all about how well we take care of their lungs
CDH Referral Pattern

- UF to Johns Hopkins All Children’s, St. Petersburg, FL
- High volume Referral Center
- High percentage of prenataly diagnosed and evaluated patients
- Expanding US and International Referrals

Repair of CDH: What matters?

- Open?
- Thoracoscopic?
- Patch?
- Which patch?

Very large Goretex patch repair

Repair: Liver in chest

A small lung
A very small lung

CDH Treatment Fundamental #2

• (2) Repair the Hernia (CDH) \( n=268 \)

<table>
<thead>
<tr>
<th>CDH Survival to Discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repaired</td>
</tr>
<tr>
<td>Not Repaired</td>
</tr>
</tbody>
</table>

Why wouldn’t a CDH be repaired?

• Severe Associated Anomalies: (10%)
  - Chromosomal
  - Cardiac (single ventricle anatomy)
  - CNS
• Repair was delayed: never got repaired
  - Repair was delayed for “stabilization” or “resolution of P. HTN”
    • Ended up on ECMO unrepaired
    • ECMO course went poorly (complications)
    • These patients are potentially recoverable

Timing of Repair

PAPERS OF THE 133RD ASA ANNUAL MEETING

Long-term Maturation of Congenital Diaphragmatic Hernia Treatment Results
Toward Development of a Severity-Specific Treatment Algorithm
David W. Kays, MD, Salameh Islam, MD, Sharon D. Larson, MD, Joy Perkins, RN, and James C. Talbert, MD

• \( N = 268 \)
• Evaluated surgical repair timing related to ECMO
  – Results stratified by anatomic severity

Annals of Surgery, 2013
Kays, Islam, Larson, Perkins, Talbert

Fundamentals of CDH Care

• 23 Years of CDH care and Research (320 CDH patients)
• 5 major lessons learned
  - Lungs (Ventilation must be lung protective. Really!)
  - Repair (required)
  - ECMO (Not all ECMO is the same)
  - Risk stratification to define care
  - Believe

ECMO: Role in CDH

• Centers with highest reported survival use ECMO
  – ECMO use averages 25 – 50% of patient
• Evaluated Surgical repair timing related to ECMO
  – Results stratified by anatomic severity
CDH

• Quantity of Survival
  – Care of lungs

• Quality of Survival
  – Care of brain

Putting a face with the numbers

- L. Liver-Up CDH
- Diagnosed prenatally at 14 weeks
- LHR 0.69
- At birth, on VA ECMO w/in 4 hours
- Repaired on ECMO at 3 days
- 2 ECMO runs lasting 29 days

Focused Protocols

• Neuro-protective
• Brain monitoring
  – NIRS
  – Biomarkers of brain injury
  – Correlation with Outcomes

Much more work to do:

• Improved Risk Stratification to refine repair timing decisions
• Development of more specific protocols:
  – Neuro protection
  – Expanded education
  – Expanded collaborations
• Defining Neurologic outcomes
  – MRI findings at discharge
  – Robust neurodevelopmental f/u
• Feeding and growth outcomes balanced with pulmonary function
  – Reported by risk stratification
• Critical Evaluation of ECMO type
• Effect of prematurity
• Long term Pulmonary HTN outcomes
• more

Passionate people and families
Thank You:

Johns Hopkins All Children’s Hospital
Johns Hopkins School of Medicine
University of Florida

Research and Program Coordinator
Joy Perkins, RN, RRT

Partners and Mentors
Paul Colombani, MD
Jonathan Ellen, MD
Saleem Islam, MD
Nicole Chandler, MD
David Burchfield, MD
Max R Langham, MD
Jon T. Wung, MD

Pediatric Surgery Fellows
Dan Neal, Statistician