Session 4: The First Minutes
Chairs: Natalie Rintoul & Anne Ades

28th April 08.30 – 10.30

10 Lung Recruitment After Birth in Infants with Congenital Diaphragmatic Hernia

K. Taylor Wild[1], Leny Mathew[1], Holly L. Hedrick[1], Natalie E. Rintoul[1], Anne Ades[1], Leane Soorkian[1], Kelle Matthews[1], Michael Posencheg[1], Erin Kesler[1], K. Taylor van Hoose[1], Howard B. Pantich[1], Elizabeth E. Foglia[1]
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12 Spontaneous Breathing Approach in Mild Congenital Diaphragmatic Hernia

Denise Oudshoorn[1], Ronny Knol[1], Suzan Cochius[1], Arjan te Pas[2], Stuart Hooper[3], Calum Roberts[3], Neysan Rafat[4], Thomas Schaible[4], Willem de Boode[5], Robin van der Lee[5], Anne Debeer[6], Florian Kipfmueller[7], Charles Roehr[8,9], Irwin Reiss[1], Philip DeKoninck[1,3]
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32 Spontaneous breathing during delivery room management in CDH neonates with very mild CDH – a case-control study

Dr. Florian Kipfmueller[1], Bartolomeo Bo[1], Lennart Hale[1], Flaminia Pugnaloni[2], Lotte Lemloh[1], Lukas Schroeder[1], Dr Bartolomeo Bo, Andreas Mueller[1]
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54 Delivery Room Resuscitation of Neonates with Congenital Diaphragmatic Hernia; Lessons Learned through Video Review

K. Taylor Wild[1], Natalie E. Rintoul[1], Holly L. Hedrick[1], Elizabeth E. Foglia[1], Anne Ades, Heidi M. Herrick[1]
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104 Umbilico-placental hemodynamics and transplacental O2 exchanges during Intact Cord Resuscitation in newborn lambs with congenital diaphragmatic hernia (CDH)

Dr Kevin Le Duc[1,2,4], Dr Florian Manoeuvrier[1], Dr Celine Rougraff[1,3], Mrs Capucine Besengez[1], Mr Julien De Jonckheere[1], Mrs Arnold Dive[1], Pr Laurent Storme[1,2,4], Dr Dyuti Sharma[1,3,4]
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Lung Recruitment After Birth in Infants with Congenital Diaphragmatic Hernia

K. Taylor Wild[1], Leny Mathew[1], Holly L. Hedrick[1], Natalie E. Rintoul[1], Anne Ades[1], Leane Soorkian[1], Kelle Matthews[1], Michael Posencheg[1], Erin Kesler[1], K. Taylor van Hoose[1], Howard B. Pantich[1], Elizabeth E. Foglia[1]
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Background: Limited data guide delivery room interventions for infants with congenital diaphragmatic hernia (CDH), and ventilatory outcomes are highly variable. Respiratory function monitoring (RFM) during initial lung aeration may provide insights into the postnatal physiology during initial stabilization after birth.

Design/Methods: Single center observational study of inborn infants with antenatally diagnosed CDH. Per protocol, infants were intubated immediately after birth, and intermittent positive pressure ventilation was initiated with peak inspiratory pressures of 20-25 cm H2O, positive end expiratory pressure of 5 cm H2O, and FiO2 of 0.3-0.5. RFM measurements were recorded with a Philips NM3 Respiratory Profile Monitor with the sensor placed between the endotracheal tube and respiratory device until transition to a ventilator. Expiratory tidal volume (TV) and end-tidal carbon dioxide level (ETCO2) were simultaneously recorded. Statistical analysis included summary statistics of demographic data. RFM parameters were summarized for each minute after birth. A non-parametric regression with a locally weighted scatterplot smoothing line was developed for TV per birthweight and ETCO2 values at each minute after birth. These values were compared for infants in subgroups defined by liver position and extracorporeal membrane oxygenation (ECMO) treatment during hospitalization.

Results: There were 50 infants with CDH studied from August 2020-December 2021 (Table 1). TV per birthweight and ETCO2 values for each minute are shown in Figures 1 and 2. Both values increased for the first 10 minutes of life, but absolute values were heterogenous across the population. TVs were overall lower and ETCO2 values higher in infants with the liver in the thoracic cavity and infants who were ultimately treated with ECMO.

Conclusion: Respiratory function immediately after birth is heterogenous for infants with CDH. Lung recruitment, as evidenced by expired TVs and ETCO2 levels, appears to be ongoing throughout the first 10 minutes after birth during invasive positive pressure ventilation.

Graph

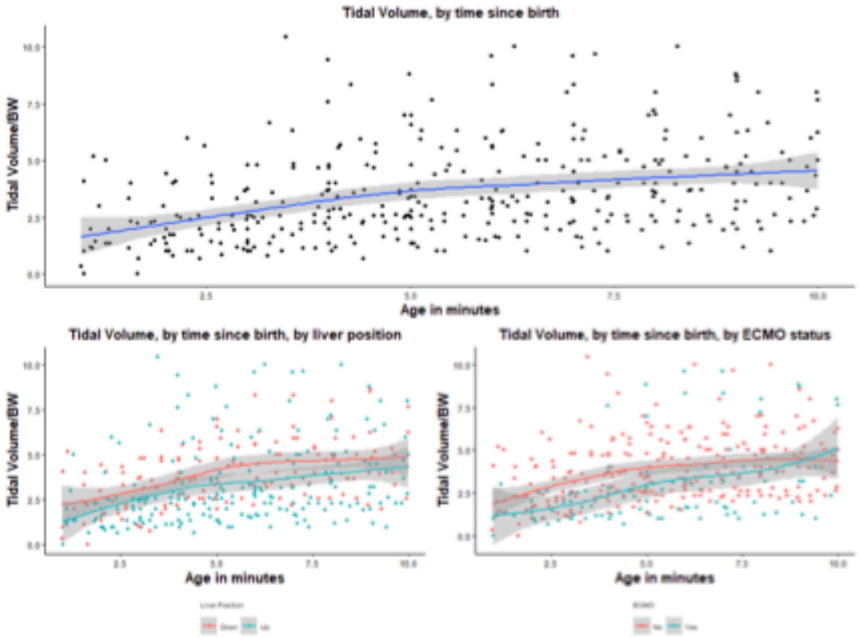

Figure 1. Tidal volume (per birthweight) over time for the first ten minutes after birth. Top panel shows the entire cohort, lower panels demonstrate subgroups based on antenatal liver position and postnatal ECMO treatment. A locally weighted scatterplot smoothing (LOWESS) line with 95% confidence interval band in gray is shown.

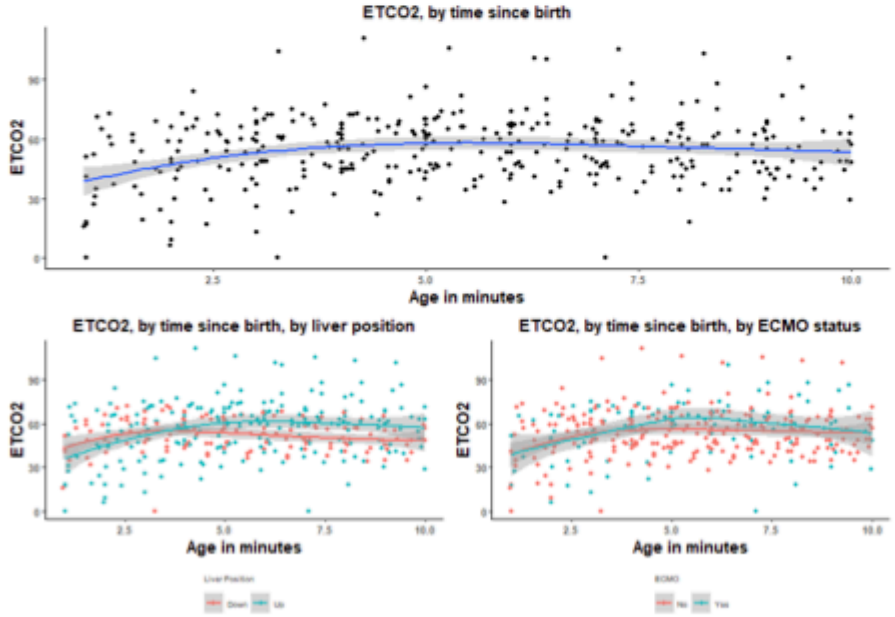

Figure 2. End tidal CO_2 over time for the first ten minutes after birth. Top panel shows the entire cohort, lower panels demonstrate subgroups based on antenatal liver position and postnatal ECMO treatment. A locally weighted scatterplot smoothing (LOWESS) line with 95% confidence interval band in gray is shown.

Images

Table 1: Characteristics of Infants with Congenital Diaphragmatic Hernia (N=50)

Characteristic	N (%), Mean ± SD, or Median (25%, 75%)
Sex (Male)	25 (50%)
CDH side (Left)	39 (78%)
Liver Position (Up)	33 (66%)
Mode of Delivery (Vaginal)	26 (52%)
Gestational Age (weeks)	37.8 ± 1.7
Birthweight (kg)	3.0 ± 0.5
LHR*	0.87 (0.60, 1.17)
O/E LHR* (%)	37.0 (28.4, 50.6)
1 min Apgar	7 (5, 8)
5 min Apgar	8 (7, 9)
Time to Pre-ductal SpO_2 > 85% (minutes)	9 (6, 9)
Time to HR > 100 beats per minute (minutes)	0 (0, 1)
First Arterial PaCO2 (mmHg) Liver Up Liver Down	62 (48, 76) 60 (48, 82) 62 (50, 69)
First Arterial PaO2 (mmHg) Liver Up Liver Down	48 (39, 67) 44 (38, 67) 53 (48, 67)

*Lung to Head Ratio (LHR) measured by mid trimester ultrasound using the trace method

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Spontaneous Breathing Approach in Mild Congenital Diaphragmatic Hernia

Denise Oudshoorn[1], Ronny Knol[1], Suzan Cochius[1], Arjan te Pas[2], Stuart Hooper[3], Calum Roberts[3], Neysan Rafat[4], Thomas Schaible[4], Willem de Boode[5], Robin van der Lee[5], Anne Debeer[6], Florian Kipfmueller[7], Charles Roehr[8,9], Irwin Reiss[1], Philip DeKoninck[1,3]

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Background: Prenatal ultrasound allows to distinguish a subgroup of infants with a congenital diaphragmatic hernia (CDH) and a relatively mild degree of pulmonary hypoplasia, corresponding with an estimated survival rate of 90%. Initial mechanical ventilation, as recommended in current guidelines, might be too aggressive for this subgroup given the favorable outcomes, the risk of ventilator-induced lung injury, and the stress caused by intubation. A trial of spontaneous breathing seemed feasible in this subgroup, but 60% of cases still required intubation in the first hours after birth. We developed a resuscitation algorithm for the spontaneous breathing approach serving two purposes: improving the success rate and providing a guideline for centers that consider implementation.

Methods: An initial protocol was drafted and discussed by all stakeholders at Erasmus MC. Secondly, the resulting protocol was refined using input from international experts.

Results: Only CDH infants with expected very mild pulmonary hypoplasia are considered candidates: left-sided defect, observed to expected lung-to-head ratio >50%, gestational age at birth ≥37.0 weeks, and no major associated structural or genetic abnormalities. Figure 1 shows the proposed algorithm. To facilitate fetal-to-neonatal transition, we suggest to start stabilisation with non-invasive respiratory support and to adjust this individually.

Conclusions: The spontaneous breathing approach is an individualized approach for infants with a relatively mild CDH. Ideally, this strategy should be tested in a randomized controlled trial. However, the lack of equipoise in centers that have already implemented this approach poses a challenge for reaching a sufficient sample size to evaluate clinically relevant outcomes. We share our current consensus protocol, so that the spontaneous breathing approach may be adopted by other centers and we strongly encourage prospective data collection within international registries such as the very mild CDH – spontaneous breathing approach (VeSBA) consortium database.

Images

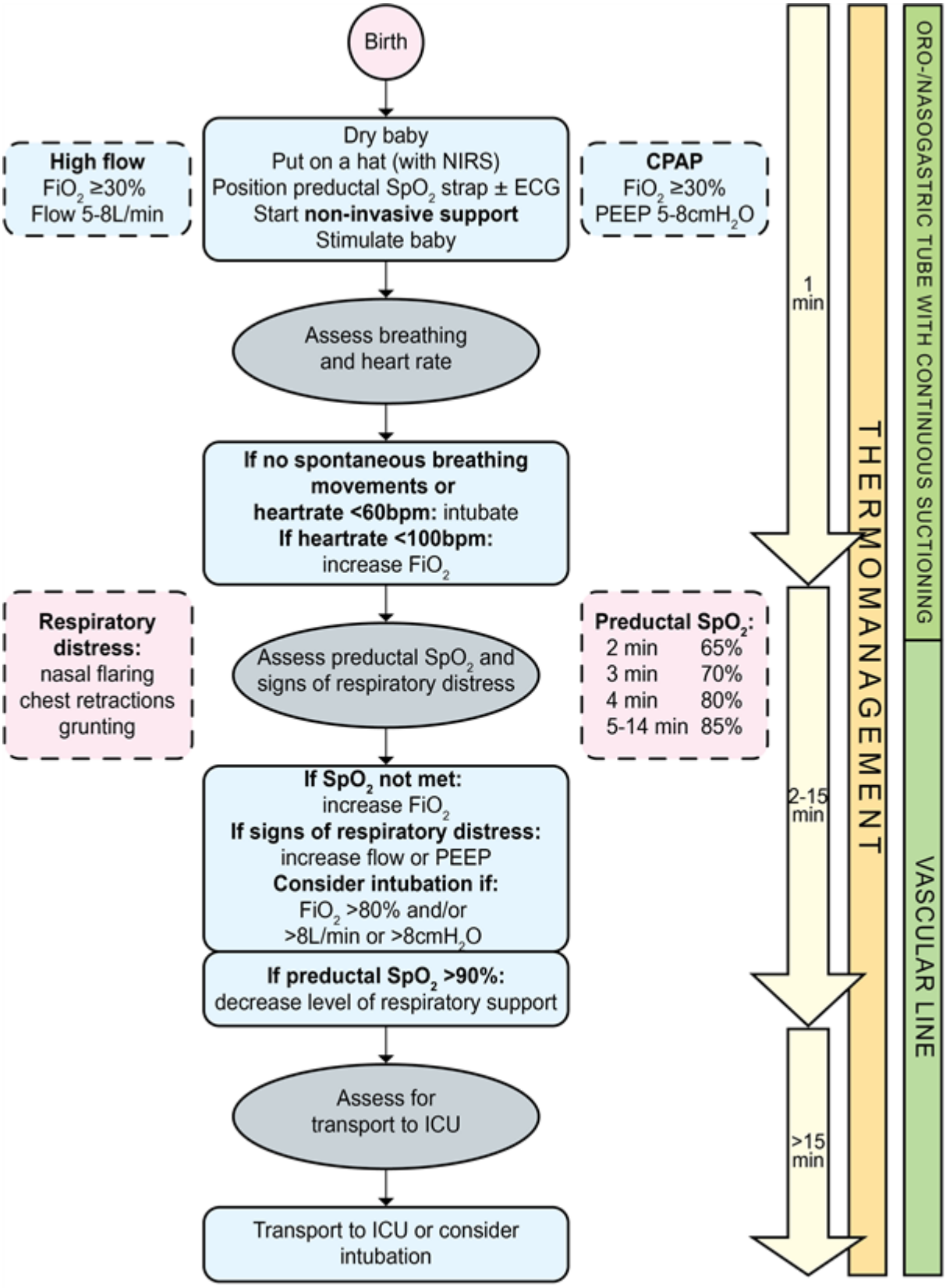

Figure 1 Flowchart spontaneous breathing approach for infants with a congenital diaphragmatic hernia

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Spontaneous breathing during delivery room management in CDH neonates with very mild CDH – a case-control study

Dr. Florian Kipfmueller[1], Bartolomeo Bo[1], Lennart Hale[1], Flaminia Pugnaloni[2], Lotte Lemloh[1], Lukas Schroeder[1], Dr Bartolomeo Bo, Andreas Mueller[1]
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Background: Immediate intubation is a key element of delivery room management in CDH neonates with prenatally diagnosed CDH. However, based on recently published studies, a spontaneous breathing approach (SBA), stabilizing the patient with no or non-invasive support, might be feasible in a subgroup of infants with very mild CDH.

Methods: Treatment and outcome data were compared for 8 neonates stabilized with SBA and 16 neonates with primary intubation (no-SBA group). Only patients with very mild CDH (defined as a o/e LHR > 45% and liver down) were included in this study. Neonates in the SBA group and the no-SBA group were matched 1:2 for o/eLHR, intraabdominal liver, gestational age, and defect size. Comparison with Mann-Whitney-U-test or Fisher's exact test, as appropriate.

Results: In 6/8 neonates in the SBA group intubation was delayed until surgical repair. Two patients were intubated at 9 and 35 minutes of age, respectively. Characteristics of both groups are summarized in table 1. Patients in the SBA group received surgical repair significantly earlier (day of life 3 vs. 5, p=0.009). Additionally, the median FiO2 prior to repair was significantly lower in the SBA group (0.25 vs. 0.35; p=0.013).
Patients in the SBA group had shorter ventilation times, a shorter length of oxygen supplementation, and were discharged earlier. Additionally, pulmonary hypertension severity was worse in the non-SBA group (moderate-to-severe PH: 44% versus 0%, p=0.004).
Patients in the SBA group showed a better systolic and diastolic function using TDI echo at baseline but not at follow-up at the day of surgery (pre-repair)

Conclusions: In neonates with very mild CDH, using SBA was associated with a shorter hospital stay and a lower duration of invasive and non-invasive therapies. CDH neonates stabilized with SBA should be enrolled in a prospective registry.

Images

	SBA (n=8)	No SBA (n=16)	p-value
Male, %	50	63	0.653
Spontaneous delivery, %	50	44	0.834
Gestational age (days)	270 (269-275)	272 (264-279)	0.976
Birth weight (kg)	3.2 (2.9-3.8)	3.4 (3.1-3.8)	0.452
Liver-Up, %	38	25	0.653
o/e LHR, %	51 (46-55)	50 (48-60)	0.383
Arterial cord blood pH	7.3 (7.26-7.34)	7.31 (7.27-7.37)	0.636
Apgar 1	7.5 (7-8)	6.5 (5-8)	0.214
Apgar 5	9 (8-10)	8.5 (7-9)	0.157
Apgar 10	**10 (9-10)**	**8.5 (7-9)**	**0.016**
FiO2, pre-OP	**25 (21-28)**	**35 (29-51)**	**0.013**
PIP, pre-OP	16.5 (15-20)	16.5 (15-19)	0.653
SpO2, pre-op	97 (96-100)	98 (97-100)	0.490
PaO2, pre-op	92 (68-109)	91 (71-111)	0.928
PCO2, pre-op	42 (40-48)	48 (43-52)	0.106
OI, pre-op	**2.1 (1.6-2.7)**	**2.8 (2.3 - 6.1)**	**0.023**
Time of Surgery, DOL	**3 (2-5)**	**5 (4-7)**	**0.009**
Defect size:			0.834
A, %	38	44	
B, %	50	44	
C, %	13	13	
Patch repair, %	0	13	0.653
Length of stay, days	**14 (10-25)**	**30 (22-47)**	**0.005**
Duration MV, days	**3.5 (2.8-6.6)**	**8.7 (6.0-9.9)**	**0.011**
Duration O2, days	**3.2 (1.1-10.6)**	**9.3 (6.9-18.9)**	**0.013**
Duration MV, post-repair, da	**1.1 (0.3-3.7)**	**3.1(2.7-4.1)**	**0.016**
Survival, %	100	100	1.0

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Delivery Room Resuscitation of Neonates with Congenital Diaphragmatic Hernia; Lessons Learned through Video Review

K. Taylor Wild[1], Natalie E. Rintoul[1], Holly L. Hedrick[1], Elizabeth E. Foglia[1], Anne Ades, Heidi M. Herrick[1]
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Background: Effective delivery room (DR) resuscitation of neonates with congenital diaphragmatic hernia (CDH) requires many critical interventions. However, timing and order of events is not well described, nor are factors that facilitate or impede CDH resuscitation. DR video recording (VR) enables accurate, in-depth resuscitation review, which may provide valuable insights into improving DR care for this high-risk population.

Objective: To describe timing and order of CDH DR interventions and identify system factors that impact CDH DR resuscitations.

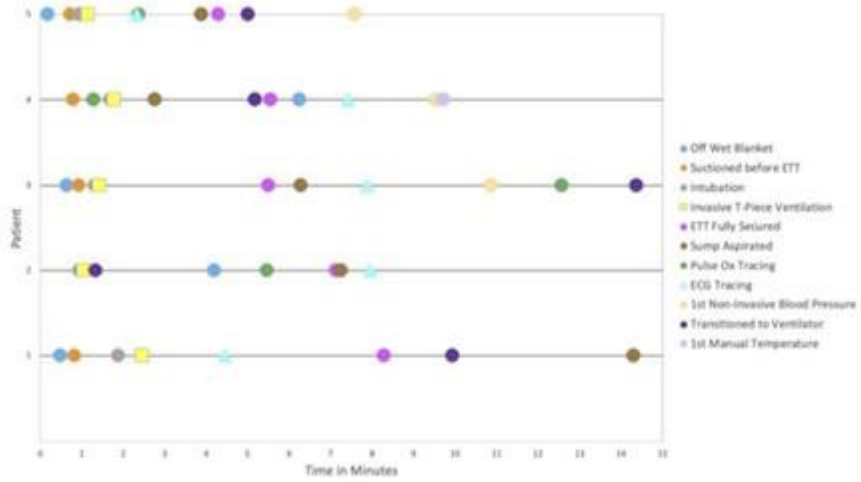
Design/Methods: Single center observational study of VR DR resuscitations of neonates prenatally diagnosed with CDH. DR VR is routine practice for quality assurance. Per unit guidelines, neonates with CDH are brought to an adjacent resuscitation room after delivery and immediately intubated. Each video was analyzed by one reviewer for event timing and initial identification of impactful system factors using the System Engineering Initiative for Patient Safety (SEIPS) model as a framework. Factors were discussed among reviewers to reach consensus and identify themes.

Results: We analyzed 5 CDH resuscitations from November-December 2021 (Table 1). Event timing and order were highly variable with the first 15 minutes of life (Figure 1). We identified 'Internal Environment' and 'Tasks' components of the SEIPS model as prominent resuscitation factors. Specifically, significant room and bed spatial constraints exist within the internal environment, and there is large task burden on the bedside nurse and respiratory therapist.

Conclusion: VR revealed variation in event timing and order during CDH resuscitations. Preparation, including equipment layout, is essential given room and bed spatial constraints. Nurses and respiratory therapists have numerous essential tasks during CDH resuscitation, making their skill and decision-making critical to effective resuscitation. Standardization of room set-up, standardization of event order, and off-loading tasks to other providers represent potential targets for CDH DR improvement initiatives.

Graph

Figure 1. Timing of DR Interventions in the First 15 Minutes of Life for Neonates with CDH



DR= Delivery Room, ETT= Endotracheal Tube, ECG= Electrocardiogram
*All interventions were completed for all patients, except patient 2 was not suctioned prior to ETT placement.

Images

Table 1: Patient and Delivery Room Characteristics

	N=5
Patient and Delivery Characteristics; N (%), Median [IQR]	
Gestation Age, weeks	38.4 [38.1-38.7]
Birth weight, grams	3140 [2700-3700]
Male	3 (60%)
Left sided CDH	4 (80%)
Liver Up	4 (80%)
LHR*	0.78 [0.58-0.87]
O/E LHR %*	39.2 [29.1-42.5]
Cesarean Section	4 (80%)
Delivery Room Practices; N (%)	
Type of Ventilator	
Conventional	1 (20%)
HFOV	4 (80%)
Sedation and Paralysis	
None	1 (20%)
Only Fentanyl	2 (40%)
Fentanyl and Vecuronium	2 (40%)
Timing of Delivery Room Interventions (in minutes after birth); Median [IQR]	
Off Wet Blanket	0.63 [0.48-4.18]
Intubation	1.32 [0.95-1.68]
Invasive T-piece Ventilation	1.42 [1.15-1.78]
Transitioned to Ventilator	5.18 [5.00-9.93]
ETT fully secured	5.55 [5.50-7.13]
Sump aspirated	6.28 [3.88-7.25]
Pulse Ox tracing	5.47 [2.37-12.57]
ECG tracing	7.42 [4.45-7.88]
1st Non-Invasive Blood Pressure	10.87 [9.55-26.67]
1st Manual Temperature	17.40 [16.38-41.83]
Xray	23.35 [21.15-41.92]
UVC	39.38 [38.67-45.00]
Arterial Access**	45.00 [45.00-52.57]
Blood Gas Resulted	48.00 [44.00-60.40]
Delivery Room Outcomes; Median [IQR]	
Apgars	
1 minute	8 [7-8]
5 minute	8 [8-8]
First Blood Gas	
pH	7.20 [7.05-7.23]
pCO2	65 [57-76]
paO2	70 [53-98]

IQR= Interquartile, CDH= Congenital Diaphragmatic Hernia, LHR= Lung to Head Ratio,
O/E= Observed to Expected, HFOV= High Frequency Oscillatory Ventilation,
ETT= Endotracheal Tube, ECG= Electrocardiogram, UVC=Umbilical Venous Catheter
*Lung to Head Ratio (LHR) measured by mid trimester ultrasounds using the trace method of the TOTAL trial
**Umbilical Artery Catheter or Peripheral Arterial Line

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Umbilico-placental hemodynamics and transplacental O2 exchanges during Intact Cord Resuscitation in newborn lambs with congenital diaphragmatic hernia (CDH)

Dr Kevin Le Duc[1,2,4], Dr Florian Manoeuvrier[1], Dr Celine Rougraff[1,3], Mrs Capucine Besengez[1], Mr Julien De Jonckheere[1], Mrs Arnold Dive[1], Pr Laurent Storme[1,2,4], Dr Dyuti Sharma[1,3,4]

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Introduction: At birth, delayed umbilical cord clamping increases blood transfusion from the placenta to the newborn which promotes cardiorespiratory adaptation.
The aim of our study is to investigate the changes in placental hemodynamics and placental gas exchanges during prolonged resuscitation with an intact cord in newborn lambs with or without CDH.

Method: At term, the fetal lamb was exteriorized through an hysterotomy of the pregnant ewe. Vascular catheters were advanced into the aorta to measure the aortic pressure (AoP). A flow transducer was placed around the vessel to measure umbilico–placental blood flow (Qup). The lamb was then exteriorized from the uterine cavity. In order to measure the umbilical vein pressure, a catheter was introduced into one of the two umbilical veins. The lambs were intubated and mechanically ventilated. Umbilico–placental vascular resistance (Rup) was calculated as: (AoP-Pv/Qup). Blood gases were measured in the Ao and umbilical vein to assess arterial (CaO2) and venous (CvO2) O2 content and transplacental O2 transfer (VO2) through: Qup*(CaO2-CvO2). The duration of the resuscitation with intact cord was 60 min.

Results: 5 CDH and 15 control lambs were included. Both AoP-Pv, Qup and Rup were similar in the 2 groups and did not change significantly through the study period (respectively, 35±8mmHg, 30±18ml/kg/min and 0.50±0.05 mmHg.min.ml-1). In the CDH group, VO2 did not change during the study period (2.8±1.2ml.kg-1.min-1), whereas VO2 decreased steadily within the first 20 min to 0.4±0.5 ml.kg-1.min-1 in the control group.

Conclusion: Our results suggest that transplacental hemodynamics are stable for up to 1 hour after birth during resuscitation while the umbilical cord is kept intact. The placenta may contributes to sustained oxygenation in the newborn with CDH. In the normal control, elevation of PaO2 reduces the O2 gradient within the umbilical vessels and the intervilli chamber, limiting O2 exchanges through the placenta.