In-person
March 13-16, 2024

Virtual
May – July 31, 2024

45th National Conference on Pediatric Health Care

Outcomes of Home Chronic Invasive Ventilation: Liberation, Decannulation and Perseveration

Ann Marie Ramsey RN, MSN, CPNP-PC
Pediatric Home Ventilator Program
CS Mott Children's Hospital
University of Michigan Health

1

Speaker Disclosure

- Nothing to disclose

2

Learning Objectives

- Explore the wide variety of medical diagnoses associated with the need for home chronic invasive ventilation.
- Discuss variables associated with successful ventilator liberation.
- Describe the characteristics associated with successful tracheostomy decannulation.

3

Questions

- What diagnosis are associated with the need for chronic mechanical ventilation?
- Which children are most likely to liberate from mechanical ventilation?
- How do children wean from ventilation in the ambulatory setting?
- What variables effect the velocity and success of ventilator liberation?
- When do children who liberate from the ventilator undergo decannulation of the tracheostomy?
- What happens to those children who are not able to wean from ventilator support?

4

Why it is important to know about chronic ventilation?

ICU SVU Home PCP Subspeciality Care School ED Community

5

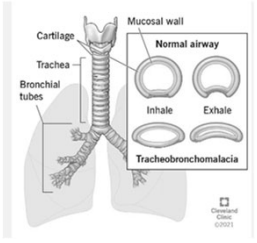
What diagnosis are associated with the need for chronic mechanical ventilation?

- Parenchymal lung disease
- Isolated airway disorders
- Thoracic restriction disorders
- Central Control of Breathing

6

Which children are most likely to liberate from mechanical ventilation?

- Children with parenchymal lung disease especially BPD
- Children with isolated airway disease



Suresh 2015, Liptzin 2016, Henningfeld 2016, Foy 2020, O'Brien 2006, Christea 2013

7

How Do Children Wean from Ventilation in the Ambulatory Setting?

- Parameters adapted from critical care weaning protocols.
- Adequacy of gas exchange (pO2, pCO2, Oxygen Saturation)
- Ventilator settings (Ipap, PEEP, RR, pressure support)
- Signs of increased work of breathing including increased respiratory rate from baseline, retractions, nasal flaring, fatigue

Santschi, et al 2007

8

Ventilator Weaning-Early Work-LTC

- Objective : Describe likelihood of ventilator/oxygen wean during inpatient stay
- Population: 34 infants & toddlers admitted to LTC for pulmonary rehab
- Weaning strategy-average LOS 21 weeks
  - Not well described
  - Pressures weaned by increments of 2 during the day
  - No discussion of night weaning
- Outcomes
  - Strongest predictor of successful ventilator weaning-diagnosis
  - Prematurity/BPD most likely to wean
  - Neuromuscular, multiple congenital anomalies less likely to wean

Kharasch (2003) Pediatric Pulmonology; 35: 280-287

9

Weaning Severity Index

Table I. Weaning severity index.

Severity	Level	Ventilator mode	PEEP (cm water)	Respiratory rate (breaths/min)	PS level
Severe	5	Volume & pressure support or pressure control	>8	No spontaneous respirations (NSR); 100% of respirations at set ventilator rate	≥20
	4	Volume & PS	6–8	Approximately half spontaneous respirations; 50% of respirations at set ventilator rate	15–19
Mild	3	PS	≤5	All breaths spontaneous; pressure support only	10–14
	2	CPAP	≤5	Pressure support with CPAP and/or spontaneous breathing trials	5–9
No support	1	0	0	No ventilator support	0

O'Brien, et al. (2006) Pediatric Rehabilitation

10

Weaning Algorithm

- Step by step process for weaning ventilator LTC
- Readiness to wean:
  - No recent escalation is support
  - Stable chest x-ray
  - pCO2 at or below 10% of baseline
  - Tolerance of adequate nutrition
  - No acute medical problems

Figure 1. Weaning algorithm.

O'Brien, et al. (2006) Pediatric Rehabilitation

11

Outcomes using Weaning Severity Index and Weaning Algorithm

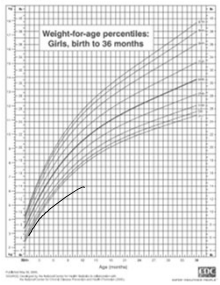
- Population: 44 infants and toddlers in the LTC with following
  - BPD N=26
  - Central control of breathing N=11
  - Airway N=5
  - Pump failure N=2
- Results
  - 20 children achieved ventilator liberation
  - 24 remained on the ventilator -5 weaned time on vent from 24 to 12 hours
  - Most prevalent diagnosis associated with liberation BPD
  - No average age at liberation reported

O'Brien, et.al. (2007) International Journal of Rehabilitation

12

Outcomes using Weaning Severity Index and Weaning Algorithm

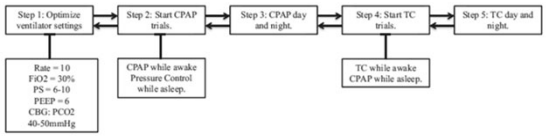
- Factors associated with delayed ventilator weaning:
  - Lack of weight gain
  - Poor tolerance for therapies
  - Scheduled surgery



O'Brien, et.al. (2007) International Journal of Rehabilitation

13

Additional Work LTC-5 step weaning protocol



Suresh, et al. (2015) Journal of Pediatric Rehabilitation Medicine: An interdisciplinary approach

14

Outcomes

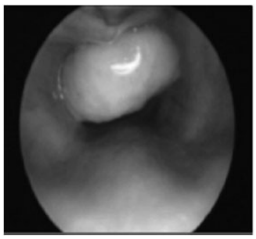
- N=5 children with BPD
- Average time to progress–time in months
  - Step 1 to Step 2= 31.2
  - Step 2 to Step 3=3.2
  - Step 3 to Step 4=1.6
  - Step 4 to Step 5=2.6
- Age at ventilator liberation
  - Range 1.7 to 8.6 years
  - Average 4.8 years

Suresh, et al. (2015) Journal of Pediatric Rehabilitation Medicine: An interdisciplinary approach

15

Variables effecting velocity of liberation

- Frequent respiratory illness
- Airway granuloma
- Poor nutritional status

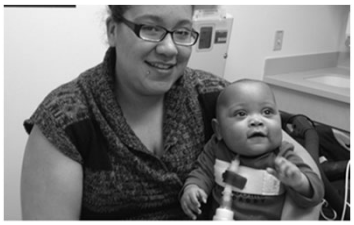


Suresh, et al. (2015) Journal of Pediatric Rehabilitation Medicine: An interdisciplinary approach

Waters, K. (2017) Respiratory Care

16

Ventilator Weaning in the Ambulatory Care Setting



17

Children's Hospital of Wisconsin

- 1999-2011
- N=46 all with Chronic Lung or Airway Anomalies, except 1 CCHS
- Weaning process-
  - "Reduction of settings", progress to trach collar day, then night
  - 62% of changes made in clinic, 37% over the phone
  - All had a polysomnogram prior to decannulation
- Outcomes:
  - Average age for ventilator liberation 25.5 months
  - Average for decannulation 40.5 months

Henningfeld (2016). Pediatric Pulmonology 51: 838-849.

18

Children's Hospital Colorado

- 2007-2014
- N=21, CLD (14), UA0 (1) combination (6)
- Weaning process
  - Does not describe procedure to get to off ventilator during the day
  - All subjects off during the day, on Cpap at night
  - Admitted for 2 nights (TCO2, VBG, CR monitoring)
  - 4 had polysomnogram prior to decannulation
- Outcomes
  - 20 liberated from ventilation average age 29 months (range 12-43)
  - 18 decannulated average age 31 months (range 7-90)

Liptzin (2016). Pediatric Pulmonology 51: 825-829.

19

C.S. MOTT CHILDREN'S HOSPITAL
UNIVERSITY OF MICHIGAN HEALTH

- Weaning process
  - Majority of children discharged using ventilator 24 hours per day
  - Initial weaning takes place in clinic
  - Clinical assessment:
    - Vital signs
    - Work of breathing
    - Transcutaneous CO2
    - Oxygen saturation
    - Tidal volume relative to weight

20

C.S. MOTT CHILDREN'S HOSPITAL
UNIVERSITY OF MICHIGAN HEALTH

- Detailed weaning process
  - First changes-reduce oxygen if using-target room air
  - Next change mode from AC to SIMV the gradually wean pressure and respiratory rate.
    - Target PEEP 8, Target Ipap lower 20's
    - If using cuffed tube deflate
  - Progressive pressure support ventilation during waking hours
  - Progressive off ventilator during waking hours
  - Pressure support ventilation during nap
  - Off ventilator at nap
  - Progressive pressure support ventilation during nighttime sleep
  - Progressive off ventilator during nighttime sleep
  - Polysomnogram prior to decannulation

21

C.S. MOTT CHILDREN'S HOSPITAL
UNIVERSITY OF MICHIGAN HEALTH

- 2012 to 2022
- N=225 children discharged on invasive ventilation
- 120 children liberated from ventilation
- Average age of ventilator liberation: 22 months
- 105 children were decannulated
- Average age of decannulation: 34 months

22

C.S. MOTT CHILDREN'S HOSPITAL
UNIVERSITY OF MICHIGAN HEALTH

- Variables associated with delayed liberation
  - Analysis of 61 children followed from 2003 to 2010
    - 29 (47%) liberated
    - 18 (30%) weaned off during the day
    - 14 (23%) did not wean
  - Change in weight was the only significant association with weaning from mechanical ventilation.
  - No association between gestational age, age at discharge, number of co-morbidities and number of exacerbations and hospitalizations and weaning from ventilator support.

Ramsey (2013) Variables affecting weaning from chronic home mechanical ventilation in children under the age of four years. Podium presentation at CHEST

23

Outcomes specific to children with BPD

- Population-
  - Infants with BPD, single center between 1984 and 2010 requiring invasive ventilation.
  - N=106
- Outcomes
  - 69 liberated from ventilation (67.6%)
  - Median age at liberation 24 months
  - 60 patients decannulated
  - Median age at decannulation 37.5 months
  - 10 patients died-cause of death unknown
  - Average age at death 27 months

Cristea, et. al. (2013) Pediatrics

24

What happens to those children who are not able to wean from ventilator support?

25

Diagnosis associated with lower likelihood of liberation

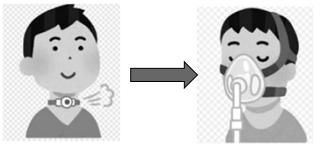
- Restrictive lung physiology due to neuromuscular disease
- Neurologically mediated respiratory failure
  - Anoxic brain injury
  - Central Apnea

Kharasch (2003) Pediatric Pulmonology;

26

Transition from Invasive to Noninvasive Ventilation

- No literature describing process
- Criteria
  - Ventilation need is nocturnal
  - Respiratory failure is chronic and not expected to change
  - Stable respiratory status
  - Candidate and family demonstrate responsibility to complete the process and comply with noninvasive therapy



27

Transition to Mask Ventilation-UM Process

- Candidate is identified and fit with a non-invasive interface to evaluate fit and tolerance at home.
- Titration polysomnogram with mask and trach capped to establish settings
- Candidate wears mask at home with trach capped for 3 months.
- Referral to otolaryngology during this time to evaluate upper airway and lower airway for decannulation barriers.
- Clinic visit after 3 months, full assessment, ventilator download reviewed.
- Notify ENT of successful transition to mask
- ENT arranges for decannulation.

28

Transition to Mask Ventilation: UM Experience

- Number of children transitioned to mask 5
- Most common diagnosis:
  - CCHS 3
  - Myelomeningocele with Chiari & hypoventilation 2
- Age at time of transition 9.2 years (range 5-14 years)
- Barriers to transition:
  - Recurrent respiratory illnesses
  - Unable to tolerate mask
  - Family unable to adhere to requirements

29

Death Rates

- Qualitative Systemic review 1980-2018
  - Median mortality 18%
  - Did not change over time
  - Cause of death
    - Progression of underlying disease (44%)
    - Respiratory event (19%)
    - LTV "accident" (11%)
    - Infection (8%)
    - Other causes (5%)
    - Unknown (9%)

Foy (2020) Pediatric Pulmonology.

30

Death Rates-UM Experience

- 2012-2022
- 225 children enrolled in the ventilator program
- 31children died for an overall mortality rate of 14%
- Cause of death
  - Accidental 19% (6)
  - Anticipated (hospice) 6% (2)
  - Disease progression anticipated 19% (6)
  - Disease progression unanticipated 32% (10)
  - Unanticipated medical complications 16% (5)
  - Unknown 6% (2)

31

Transition to Adult Care-UM Model

- "Mirror" pediatric ventilator program
- Transition clinic twice yearly
- Statistics: 87 invasively ventilated young adults transitioned to adult since 2009
  - Neuromuscular 58% (51)
  - Spinal Cord Injury 17% (15)
  - Encephalopathy 8% (7)
  - CCHS 9% (8)
  - Other 7% (6)

32

References

- Suresh, W., Huxol, H.G. & Morton, R.L. (2015) Decreasing mechanical ventilator support in medically fragile children with bronchopulmonary dysphasia: A step-by step weaning protocol at a pediatric long term care facility. *Journal of Pediatric Rehabilitation Medicine: An interdisciplinary approach 8.* 147-156. DOI 10.3233/PRM-150328
- Foy., C, Koncicki M., Edwards., J (2020). Liberation and mortality outcomes in pediatric long term ventilation: A qualitative systematic review. *Pediatric Pulmonology.* (55): 2835-2862. DOI: 10.1002/ppul.25003
- Henningfield, J., Maletta, K., Ren, B., Richards, K., Wegner, C., & D'Andrea, L. (2016). Liberation from home mechanical ventilation and decannulation in children. *Pediatric Pulmonology*. (51): 838-849. DOI: 10.1002/ppul.23396
- Liptzin, D., Connell, E., Marable, J., Marks, J., Thrasher, J., & Baker, C. (2016). Weaning nocturnal ventilation and decannulation in a pediatric ventilator care program. *Pediatric Pulmonology*. (51): 825-829. DOI: 10.1002/ppul.23436
- Mastouri, M, Amaddeo, A, Griffon, L, Frapin, A, Touil, S, Ramirez, A, Khirani, S, & Fauroux, B (2017). Weaning from long term continous positive airway pressure or non invasive ventilation in children. *Pediatric Pulmonology* 52: 1349-1354. DOI: 10.1002/ppul.23767

33

References

- O'Brien, J. E., Dumas, H. M., Haley, S. M., Ladenheim, B., Mast, J., Burke, S. & Kharasch, V. S. (2007), Ventilator weaning outcomes in chronic respiratory failure in children. *International Journal of Rehabilitation* 30: 171-174.
- O'Brien, J. E., Birnkrant, D. J., Dumas, H. M., Haley, S. M., Burke, S. A., Graham, R. J., & Kharasch, V. S. Weaning children from mechanical ventilation in a post-acute care setting. Pediatric Rehabilitation 2006; 9: 365-372
- Cristea, A.I., Carroll, A.E., Davis, S.D., Swigonski, N.L., and Ackerman, V.L. (2013) Outcomes of children with severe bronchopulmonary dysplasia who were ventilator dependent at home. *Pediatrics* 132: e727-e734.
- Kharasch, V. S., Haley, S. M., Dumas, H. M., Ludlow, L. H., & O'Brien, J. E. (2003). Oxygen and ventilator weaning during inpatient pediatric pulmonary rehabilitation. *Pediatric Pulmonology*; 35: 280-287.
- Santschi, M., Gauvin F., Hatzakis, G., Lacrois, J., and Jouvet, P. (2007). Acceptable respiratory physiologic limits for children during weaning from mechanical ventilation. *Intensive Care Medicine* 33: 319-325. DOI 10.1007/s00134-006-0414-0
- Suresh, S, Huxol, H.G., Morton, R.L (2015). Decreasing mechanical ventilator support in medically fragile children with bronchopulmonary dysplasia: A step by step weaning protocol at a pediatric long term care facility. *Journal of Pediatric Rehabilitation Medicine: An interdisciplinary approach*. 8:147-156

34

References

- Henningfeld, J.K., Maletta, K., Ren, B.,, Richards, K.L., Wegner, C., and D'Andrea, L. (2016). Liberation from home mechanical ventilation and decannulation in children. *Pediatric Pulmonology* 51: 838-849.
- Liptzin, D., Connell, E.A., Marable, J., Marks, J., Thrasher, J., and Baker, C.D. (2016). Weaning nocturnal ventilation and decannulation in a pediatric ventilator care program. *Pediatric Pulmonology* 51: 825-829.
- Ramsey, A.M., Covrigaru, L., Barnum, K., Benneyworth, B., Murphy, S, and Filbrun, A. Variables affecting weaning from chronic home mechanical ventilation in children under the age of four years. Accepted for podium presentation at CHEST, October 30, 2013
- Foy, C.M., Koncicki, M.L., and Edwards, J.E. (2020). Liberation and mortality outcomes in pediatric long-term ventilation: A qualitative systemic review. *Pediatric Pulmonology* 55: 2853-2862.
- Waters, K. (2017). Tracheostomy in children. *Respiratory Care* 62: 799-825.

35