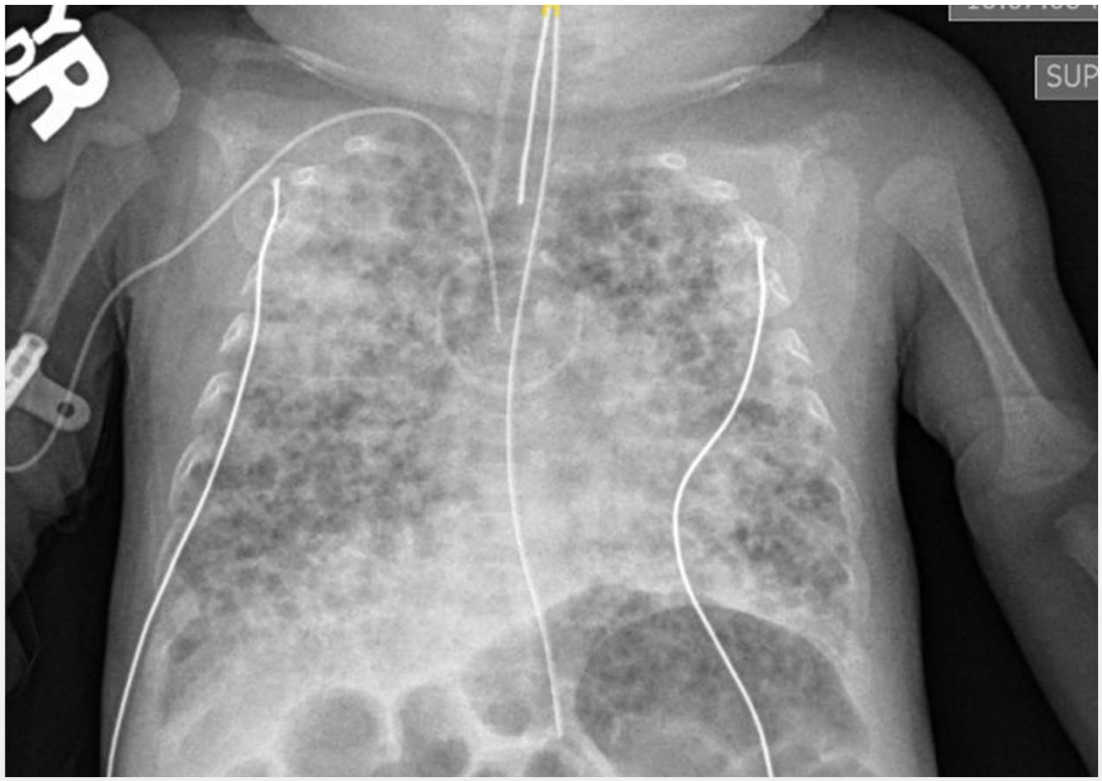
Established BPD Ventilation Strategy

Amy Holden RRT, B.Sc



Severe Bronchopulmonary Dysplasia

- Heterogenous disease process with variations in airway resistance and lung compliance in different regions of the lung (fast and slow compartments)
- Characterized by gas trapping, lung overinflation, V̇/Q̇ mismatch
- Results in high oxygen demand, respiratory discomfort, increased work of breathing, and frequent hypoxemic episodes

Goals of BPD ventilation strategy

- Longer inspiratory times to overcome increased airway resistance and deliver adequate tidal volumes to achieve optimal V̇/Q̇ matching
- Lower respiratory rates to increase expiratory time, facilitate complete exhalation, and reduce gas trapping
- Higher tidal volumes are required to maintain adequate minute ventilation - typically a minimum of 250 ml/min/kg

Inclusion Criteria

- Infants > 28 days of age AND ≥ 34 weeks PMA requiring supplemental oxygen and mechanical ventilation secondary to lung disease of prematurity

- Infants > 28 days of age AND ≥ 32 weeks PMA may be considered in the context of severe heterogeneous lung disease of prematurity ***AND*** the infant is no longer tolerating optimized high-frequency ventilation strategies (HFJV, HFOV).

Important Note

The most appropriate PMA for transitioning from a small VT/high-rate strategy aimed at preventing BPD to a large VT/low-rate strategy aimed at managing established BPD/heterogeneous CLD has not been determined. The transition phase may be identified when the small VT/high-rate strategy is no longer effective. The decision to switch strategies at < 32 weeks should be made after careful consideration and a team discussion of benefits versus risks.

Exclusion Criteria

- Term infants
- Preterm infants less than 28 days of age
- Homogeneous lung disease on chest x-ray

Relative Exclusion Criteria

- Large ETT leaks – consider ETT upsize or switch to microcuff ETT

Initial Settings

For the most accurate evaluation, it is advisable to change modes while the patient is in a calm state

Mode: SIMV +VG

RR: 10-20 bpm

VG: 8-12 ml/kg

PEEP: set to target MAP equal to HFV MAP, titrate according to FiO2 and FV loops

Ti: 0.6-1.0 sec, adjust according to flow-time scalar to optimize patient-ventilator synchrony

Slope: 1/3rd of Ti (i.e. for Ti 0.6 sec, slope should be set at 0.2 sec)

PS: 10-12 cmH2O, adjust according to work of breathing to overcome airway resistance

FiO2: to achieve SpO2 target

MV: approx 250 ml/min/kg

To reduce risk of gas trapping…

If RR 10 bpm, VG 10-12 ml/kg

If RR 15 bpm, VG 9-10 ml/kg

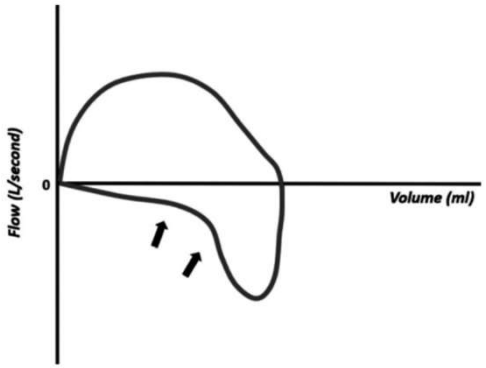
If RR 20 bpm, VG 8-9 ml/kg

Setting Titration

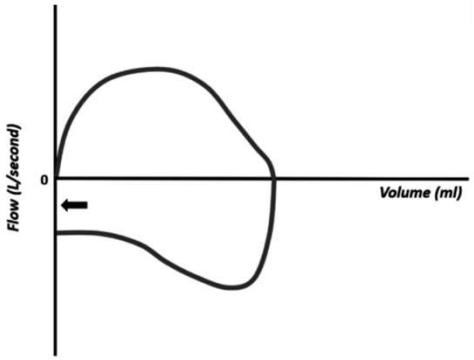
Assessment	Action
Ensure the patient is in a calm state	Use comfort care measures and avoid handling to achieve a calm state. Do not increase sedation.
Evaluate PV and FV loops to determine a baseline	Consider taking a photo of the loops if hospital policy allows. At SickKids, Rover app can be used to capture and upload photo into EPIC as pre-assessment loops.*
Observe baseline RR at rest	If resting RR is > 35 bpm, gradually increase VG until resting RR is less than 35 bpm over 5-15 min, up to a maximum VG of 12 ml/kg.
Evaluate flow scaler to ensure a brief expiratory pause before the next breath.	If no expiratory pause, gradually increase VT until an expiratory pause is achieved, up to a maximum of 12 ml/kg.
Evaluate FV loops for expiratory flow obstruction.	If expiratory flow obstruction is present, gradually increase PEEP by 1-2 and reassess.

What are we looking for?

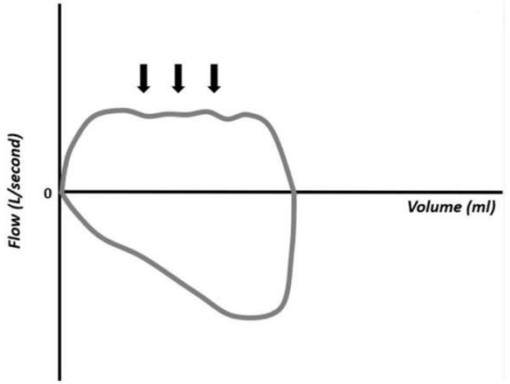
Expiratory Flow Obstruction



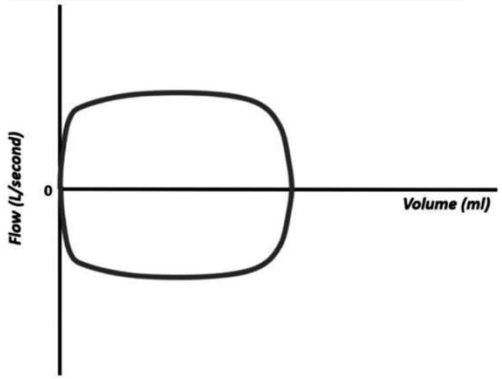
Gas trapping



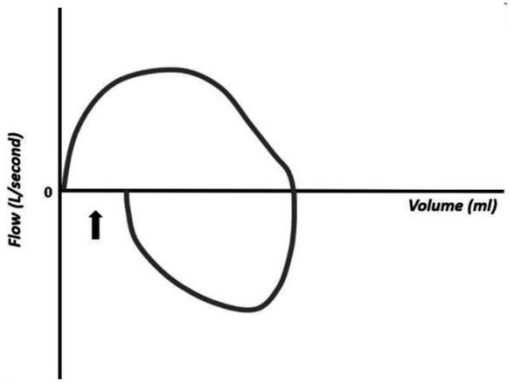
Intra-thoracic Inspiratory Flow Obstruction



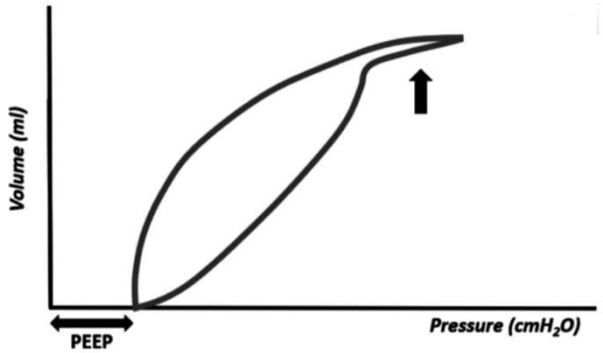
Fixed extra-thoracic obstruction



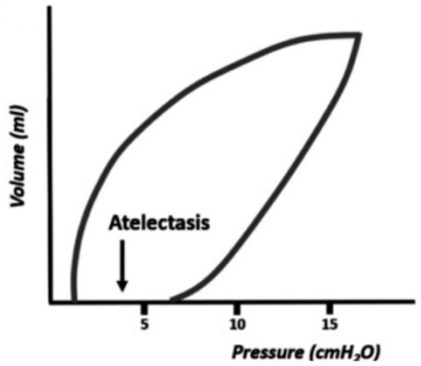
ETT Leak



Pulmonary Overdistension



Atelectasis



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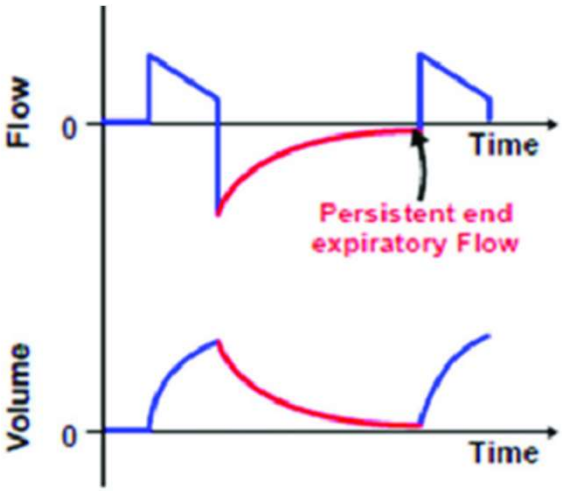

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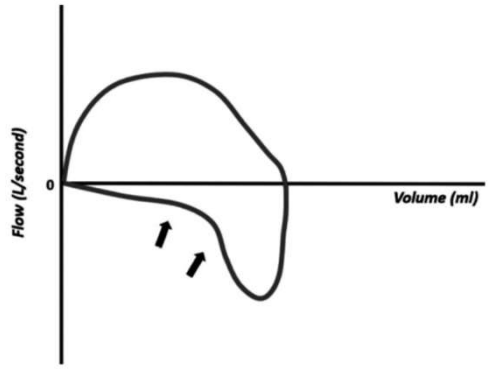
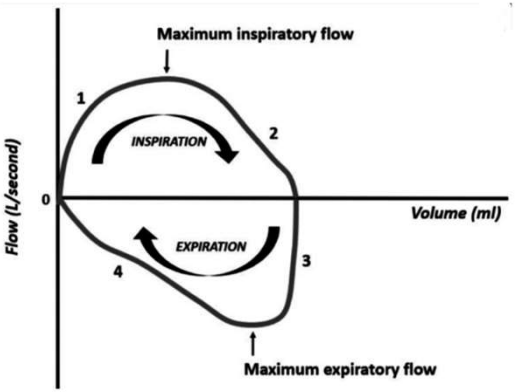
Evaluate flow scaler to ensure a brief expiratory pause before the next breath.	If no expiratory pause, a sign of gas trapping, gradually increase VT until an expiratory pause is achieved, up to a maximum of 12 ml/kg. *
Evaluate FV loops for expiratory flow obstruction.	If expiratory flow obstruction is present, gradually increase PEEP by 1-2 and reassess.

Setting Titration

Expiratory Flow Obstruction



Normal Flow Volume Loop



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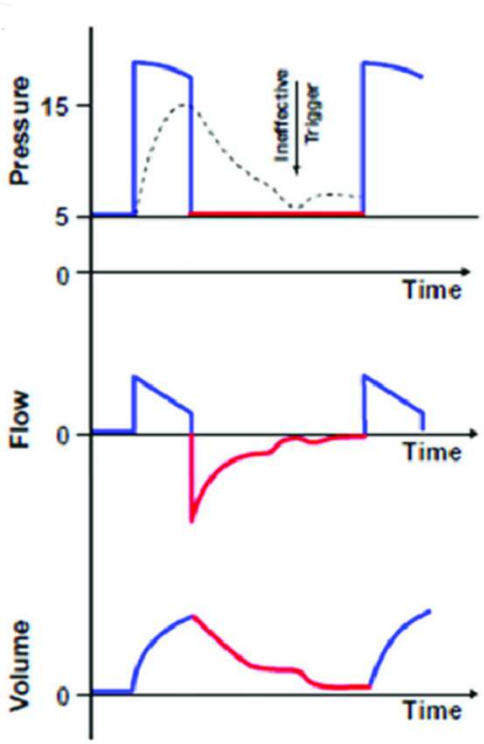

Assessment	Action
Look for patient inspiratory efforts not resulting in a ventilator-supported breath	If patient unable to trigger, decrease the flow trigger (0.2-0.3 lpm on VN500, 0.1-0.3 lpm on Servo). The inability to trigger could be due to: 1) autoPEEP - gradually increase PEEP until all efforts result in a patient breath 2) Excessive hyperinflation (inspect PV loops & consider CXR to inspect hemi-diaphragms and heart size) – monitor SpO2 and gradually wean PEEP by 1 or 2 cmH2O and look for improvement in patient-triggering *
Examine flow scalars for adequacy of I-time	If there is no inspiratory pause, no significant ETT leak, and end-inspiratory flow is still positive, increase I-time by 0.05-0.1 sec and reassess. If inspiratory pause seen, decrease I-time by 0.05-0.1 sec and reassess.
Assessment complete	Use Rover app to capture and upload photo into EPIC as post-assessment loops.

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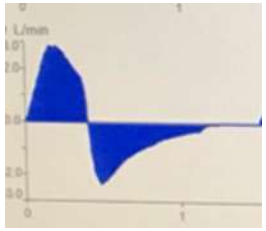

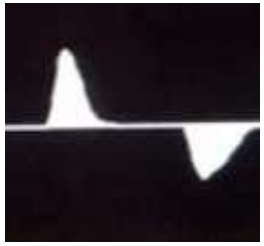

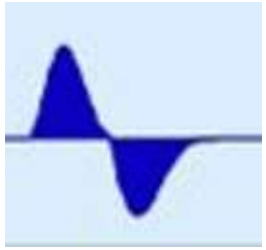

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Examine flow scalars for adequacy of I-time	If there is no inspiratory pause, no significant ETT leak, and end-inspiratory flow is still positive*, increase I-time by 0.05-0.1 sec and reassess. If inspiratory pause seen*, decrease I-time by 0.05-0.1 sec and reassess.*
Assessment complete	Use Rover app to capture and upload photo into EPIC as post-assessment loops.

Patient History

Male infant, GA: 25 weeks BW: 670 g

Emergency c-section due to antepartum hemorrhage

Antenatal steroids not given

Apgars 4, 6, 8

Intubated at 5 min, Curosurf x1, iNO x 14 hours, HFJV

Early chronic changes noted on CXR

DART at 27 weeks PMA with poor response

DART D/C'd early due to increasing abdo distention

HFJV RR 240 bpm, PIP 43, PEEP 12, Ti 0.022 s, FiO2 0.7-1.0

Transferred to SickKids at 28 weeks + 2 days PMA for segmental volvulus with necrosis, 30 cm distal ileum resected

SickKids Admission X-ray

Respiratory Course at SickKids

Managed on HFOV during bedside OR, then transitioned to HFJV for FiO2 0.8-1.0 and cystic changes on CXR

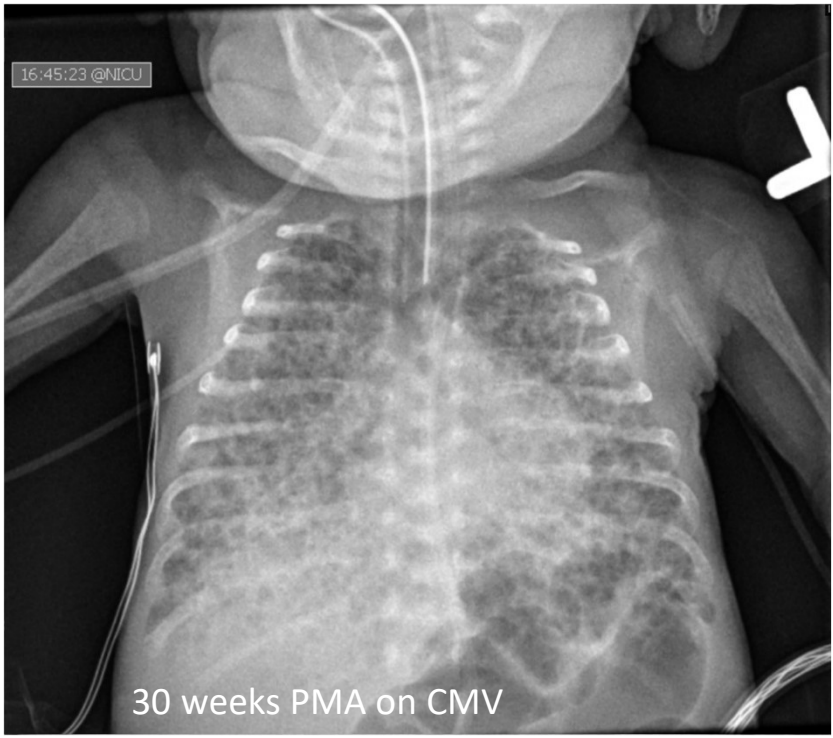
28 – 29 weeks PMA remained on HFJV, baseline FiO2 0.4-0.65

29 weeks + 5 days PMA – UPE, ETT up-sized from #2.5 to #3.0, had brief period of reduced FiO2 needs but then needed 0.6-0.8

30 weeks + 1 day – trials of HFOV and CMV with no clinical improvement and worsening of CXR *

30 weeks + 2 days – back to HFJV, baseline FiO2 0.45-0.65

30 weeks + 4 days – 2nd course of DART, stopped after 4 days due to no improvement



30 weeks PMA on CMV

Respiratory Course at SickKids

Patient required FiO2 0.8-1.0 for cares

Frequent desaturations to SpO2 50-65% requiring FiO2 1.0 and sometimes manual ventilation to recover*

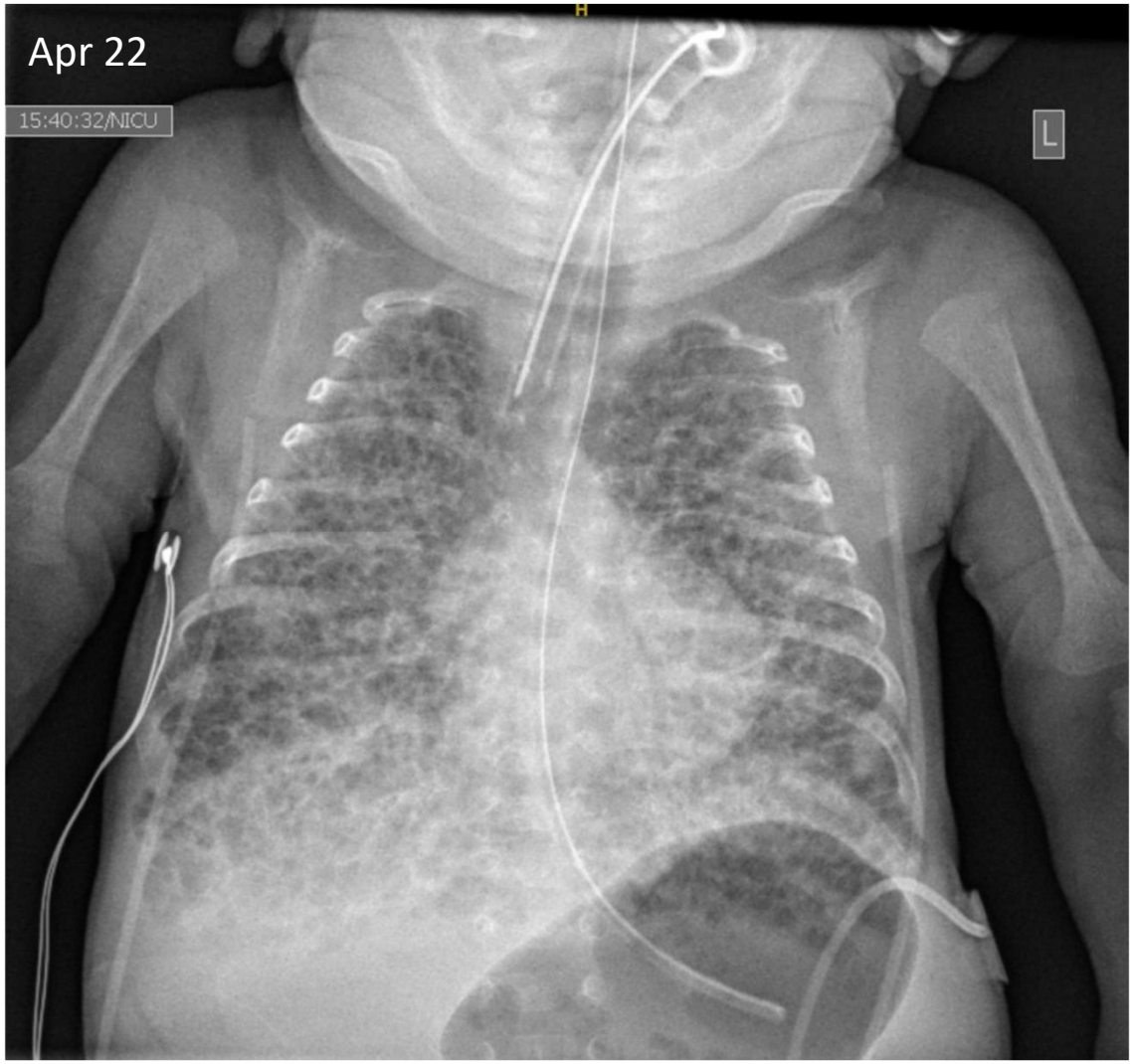
31 weeks + 1 day – HFJV + sigh breaths and FiO2 0.84-1.0.
Significant atelectasis on CXR - switched to HFOV with MAP 20

31 – 32 weeks - HFOV, FiO2 0.65-0.9*
Patient required FiO2 0.9-1.0 with handling and continued to have desaturations to SpO2 55-65%

32 weeks + 4 days PMA – initiated the established BPD ventilation strategy

32 weeks PMA on HFOV

Date	22-Apr	23-Apr	27-Apr	28-Apr		
Time	13:24	21:55	9:45	4:23	16:48	20:53
HR	156	144	150	136	146	143
SpO2	97	95	98	94	92	96
FiO2	0.72	0.62	0.5	0.53	0.46	0.49
TcPCO2	72.5	90	89.6	77	83.9	79
EtCO2						
Mode	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG
RR (set)	20				20	20
RR (total)	30				29	33
PIP (meas)	25	30	31	35	38	29
PEEP (set)	10					10
Ti	0.6					0.6
Slope	0.2					0.2
Psupport	10					10
MAP	13					14
VG (set)	8.5	9	9.5	10.4	12	10.2
VG (ml/kg)	8.5	9	8.6	9.45	10	8.5
MV	0.22	0.26				0.28
Trigger	0.4					0.4
Pmax	32					36
Rational		High TcPCO2	High TcPCO2	CBG	High TcPCO2	CBG
Date	21-Apr	23-Apr	25-Apr	28-Apr		28-Apr
Time	3:46	4:15	6:04	4:01		19:48
Source	CBG	CBG	CBG	CBG		CBG
pH	7.34	7.38	7.34	7.31		7.42
PCO2	58	56	68	70		59
PO2	33	45	62	59		37
HCO3	31	34	37	35		38
BE	4	7	9	7		12
TcPCO2	73	75	79	81		79
Meds	morphine 14 mcg/kg/hr, spironolactone 1 mg, clonadine 1 mcg/kg		morphine decreased to 12	morphine 10, spironolactone 1 mg, clonadine 2 mcg/kg		



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PIP (meas)	25	30	31	35	38	29
PEEP (set)	10					10
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Slope	0.2					0.2
Psupport	10					10
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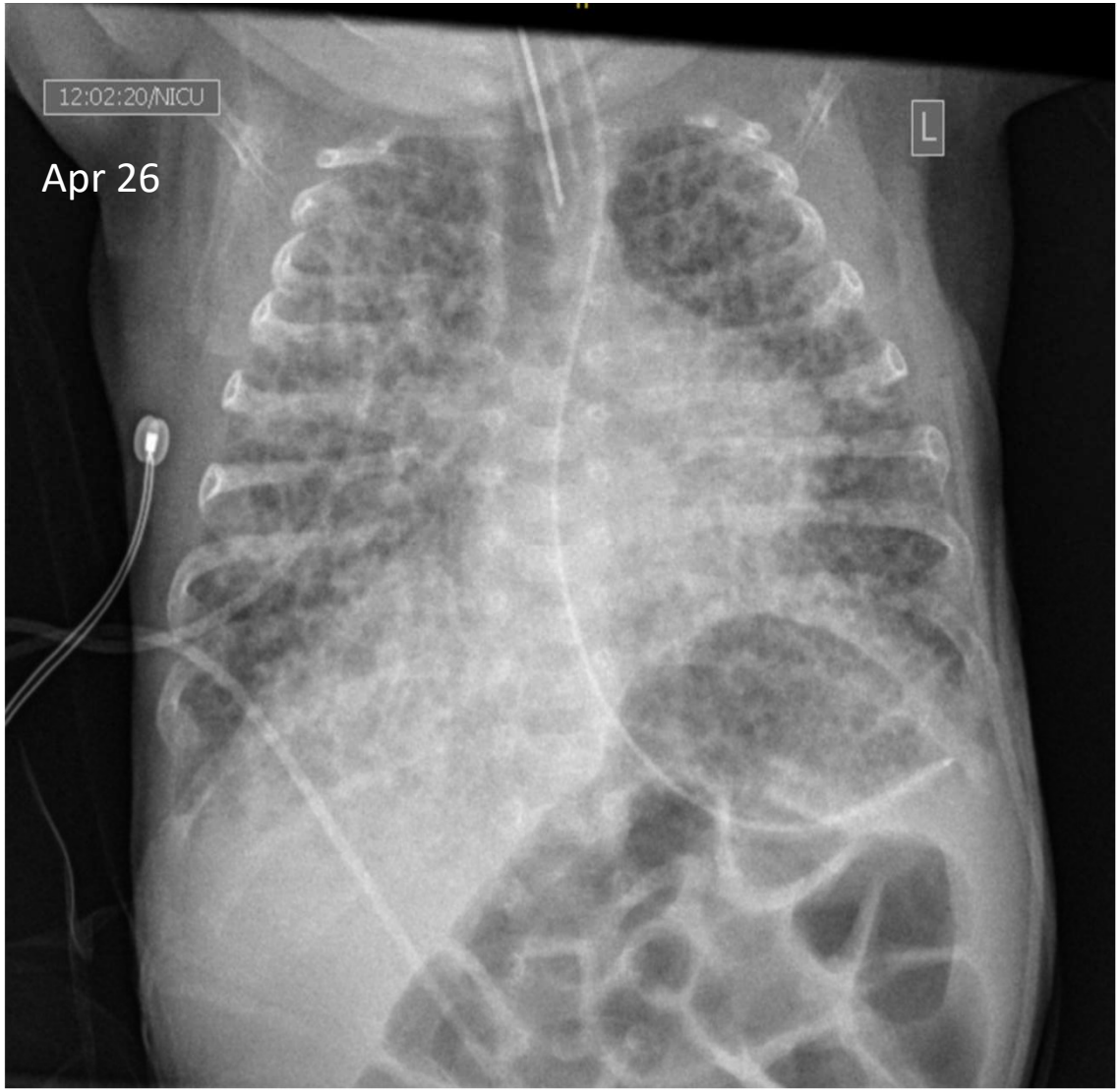

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RR (total)	30				29	33			38	37
PIP (meas)	25	30	31	35	38	29		33	28	37
PEEP (set)	10					10			9	9
Ti	0.6					0.6			0.6	0.8
Slope	0.2					0.2			0.2	0.25
Psupport	10					10			10	10
MAP	13					14			13	
VG (set)	8.5	9	9.5	10.4	12	10.2		10.8	10.8	11.7
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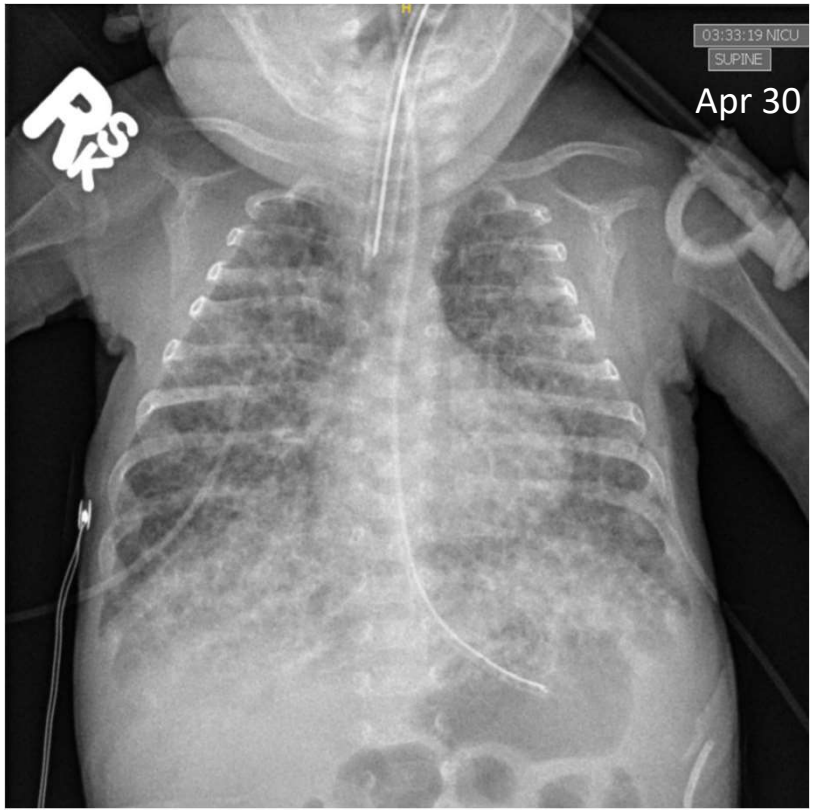

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EtCO2							53	48	55		
Mode	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG
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MAP	13					14			13		16
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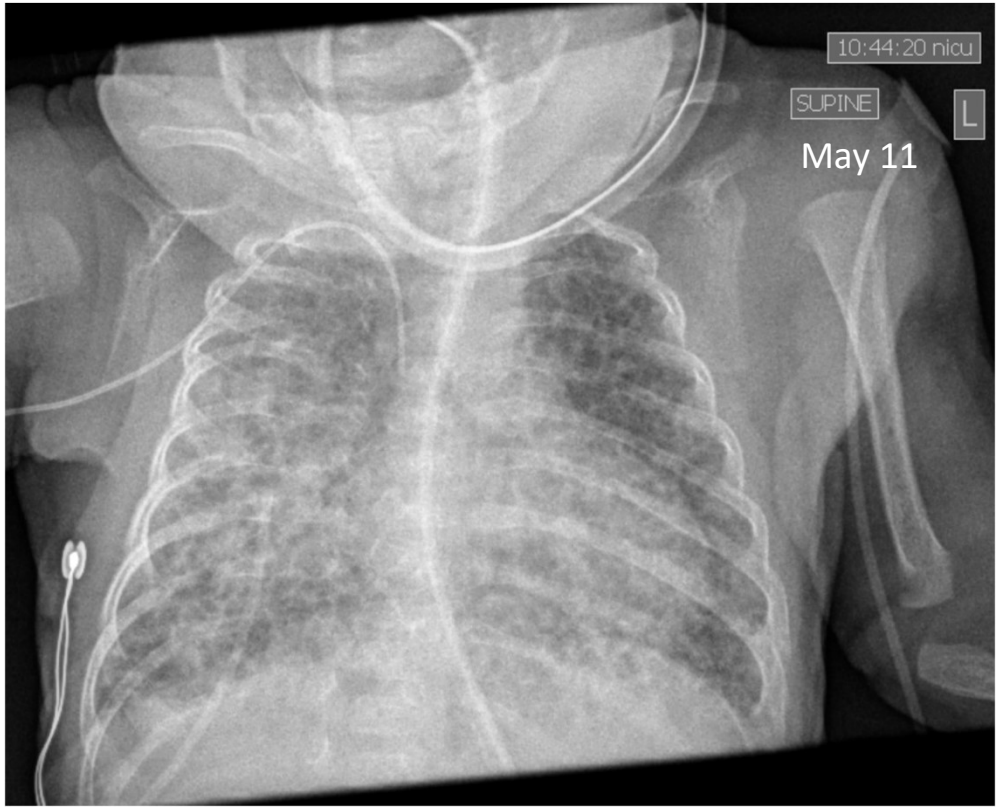
TcPCO2	73	75	79	81		79		Et 50		Et 58	79

Meds					
	morphine 14 mcg/kg/hr, spironolactone 1 mg, clonadine 1 mcg/kg	morphine decreased to 12	morphine 10, spironolactone 1 mg, clonadine 2 mcg/kg	morphine 8, spironolactone 1 mg, clonadine 2 mcg/kg	morphine 6, spironolactone 1.5 mg, clonadine 3 mcg/kg, budesonide

Date	22-Apr	23-Apr	27-Apr	28-Apr			29-Apr	30-Apr	01-May	02-May	04-May	06-May
Time	13:24	21:55	9:45	4:23	16:48	20:53	11:36	4:37	11:49	16:27	14:50	14:30
HR	156	144	150	136	146	143	149	145	157	152	147	159
SpO2	97	95	98	94	92	96	97	90	94	95	92	95
FiO2	0.72	0.62	0.5	0.53	0.46	0.49	0.5	0.45	0.45	0.5	0.52	0.55
TcPCO2	72.5	90	89.6	77	83.9	79				70	85.6	75.2
EtCO2							53	48	55			
Mode	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	NIV CMV
RR (set)	20				20	20	15	15	15	15	15	40
RR (total)	30				29	33			38	37	38	
PIP (meas)	25	30	31	35	38	29		33	28	37	28	24
PEEP (set)	10					10			9	9	9	12
Ti	0.6					0.6			0.6	0.8	0.8	0.8
Slope	0.2					0.2			0.2	0.25	0.25	0.2
Psupport	10					10			10	10	10	
MAP	13					14			13		16	15
VG (set)	8.5	9	9.5	10.4	12	10.2		10.8	10.8	11.7	12.4	
VG (ml/kg)	8.5	9	8.6	9.45	10	8.5		9	9	9	9.5	
MV	0.22	0.26				0.28			0.4		0.35	
Trigger	0.4					0.4			0.4		0.4	
Pmax	32					36			42		35	
Rational		High TcPCO2	High TcPCO2	CBG	High TcPCO2	CBG	wean	CBG	wean	ETT leak, CBG		Extubated
Date	21-Apr	23-Apr	25-Apr	28-Apr		28-Apr		30-Apr		02-May	03-May	06-May
Time	3:46	4:15	6:04	4:01		19:48		4:10		6:24	23:36	3:59
Source	CBG	CBG	CBG	CBG		CBG		CBG		CBG	CBG	CBG
pH	7.34	7.38	7.34	7.31		7.42		7.29		7.37	7.34	7.34
PCO2	58	56	68	70		59		72		73	73	74
PO2	33	45	62	59		37		41		47	58	37
HCO3	31	34	37	35		38		34		42	39	40
BE	4	7	9	7		12		6		14	10	11
TcPCO2	73	75	79	81		79		Et 50		Et 58	79	79
Meds	morphine 14 mcg/kg/hr, spironolactone 1 mg, clonadine 1 mcg/kg		morphine decreased to 12	morphine 10, spironolactone 1 mg, clonadine 2 mcg/kg			morphine 8, spironolactone 1 mg, clonadine 2 mcg/kg				morphine 6, spironolactone 1.5 mg, clonadine 3 mcg/kg, budesonide	

Date	22-Apr	23-Apr	27-Apr	28-Apr			29-Apr	30-Apr	01-May	02-May	04-May	06-May	12-May	13-May	15-May	17-May	19-May
Time	13:24	21:55	9:45	4:23	16:48	20:53	11:36	4:37	11:49	16:27	14:50	14:30	8:33	12:47	8:39	12:01	9:14
HR	156	144	150	136	146	143	149	145	157	152	147	159	149	131	140	153	146
SpO2	97	95	98	94	92	96	97	90	94	95	92	95	96	96	93	93	94
FiO2	0.72	0.62	0.5	0.53	0.46	0.49	0.5	0.45	0.45	0.5	0.52	0.55	0.35	0.3	0.26	0.28	0.24
TcPCO2	72.5	90	89.6	77	83.9	79				70	85.6	75.2					
EtCO2							53	48	55								
Mode	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	SIMV+VG	NIV CMV	NIV CMV	NIV CMV	NIV CMV	NIV CMV	NCPAP
RR (set)	20				20	20	15	15	15	15	15	40	40				
RR (total)	30				29	33			38	37	38						
PIP (meas)	25	30	31	35	38	29		33	28	37	28	24	22	21	20	19	
PEEP (set)	10					10			9	9	9	12		11	10	9	12
Ti	0.6					0.6			0.6	0.8	0.8	0.8	0.75				
Slope	0.2					0.2			0.2	0.25	0.25	0.2	0.1				
Psupport	10					10			10	10	10						
MAP	13					14			13		16	15	15	14	13	11	
VG (set)	8.5	9	9.5	10.4	12	10.2		10.8	10.8	11.7	12.4						
VG (ml/kg)	8.5	9	8.6	9.45	10	8.5		9	9	9	9.5						
MV	0.22	0.26				0.28			0.4		0.35						
Trigger	0.4					0.4			0.4		0.4						
Pmax	32					36			42		35						
Rational		High TcPCO2	High TcPCO2	CBG	High TcPCO2	CBG	wean	CBG	wean	ETT leak, CBG		Extubated					
Date	21-Apr	23-Apr	25-Apr	28-Apr		28-Apr		30-Apr		02-May	03-May	06-May	12-May			16-May	19-May
Time	3:46	4:15	6:04	4:01		19:48		4:10		6:24	23:36	3:59	8:15			8:01	8:07
Source	CBG	CBG	CBG	CBG		CBG		CBG		CBG	CBG	CBG	CBG			CBG	CBG
pH	7.34	7.38	7.34	7.31		7.42		7.29		7.37	7.34	7.34	7.45			7.34	7.35
PCO2	58	56	68	70		59		72		73	73	74	63			62	61
PO2	33	45	62	59		37		41		47	58	37	46			47	41
HCO3	31	34	37	35		38		34		42	39	40	44			33	34
BE	4	7	9	7		12		6		14	10	11	16			6	6
TcPCO2	73	75	79	81		79		Et 50		Et 58	79	79	85				
Meds	morphine 14 mcg/kg/hr, spironolactone 1 mg, clonadine 1 mcg/kg		morphine decreased to 12	morphine 10, spironolactone 1 mg, clonadine 2 mcg/kg			morphine 8, spironolactone 1 mg, clonadine 2 mcg/kg				morphine 6, spironolactone 1.5 mg, clonadine 3 mcg/kg, budesonide		morphine 3 mcg/kg, lasix 1 mg/kg, clonadine 3.5, budesonide		spironolactone 2, clonadine 4		

CXR after extubation to NIV CMV



Summary

- Patient born at 25 weeks GA, birth weight 670 g
- Volvulus and bowel resection at 28 weeks PMA
- Patient on high FiO2 requirements on HFJV and HFOV, unable to wean settings
- No improvement with DART
- Not tolerating cares, needing FiO2 0.8-1.0 for handling
- Frequent significant desaturations requiring FiO2 1.0 and sometimes manual ventilation to recover
- Patient switched to established BPD strategy at 32 weeks + 4 days
- Sedation weaned progressively after switch to SIMV+VG
- Extubated 14 days later to NIV CMV
- 13 days after extubation – FiO2 < 0.3 and switched to NCPAP

Take Home Points

- Use established BPD strategy only if patient has heterogeneous lung disease of prematurity, is > 28 days of age, and is no longer tolerating optimized high-frequency ventilation
  - high FiO_2 > 0.6, significant work of breathing, not tolerating handling, significant desaturation +/- bradycardia episodes, unable to wean HFV settings

- Titrate set RR and VG to maintain adequate minute ventilation, meet PCO_2 targets, and keep total RR $\leq$ 35 bpm to maximize time for exhalation

- Set Ti according to flow-time waveform and set slope/rise time to 1/3rd of the Ti to optimize patient comfort and reduce asynchrony with the ventilator

- Titrate Psupport according to work of breathing and increase to decrease total RR

- Adjust PEEP based on FiO_2 requirements and flow-volume loops (gas trapping and expiratory flow obstruction)

- Take care not to confuse gas trapping on CXR with hyperinflation from high PEEP; weaning PEEP may cause airway collapse and worsen gas trapping

- Look for patient efforts not rewarded with a breath – consider decreasing the flow trigger, or increasing the PEEP if significant gas trapping is suspected


ANY
QUESTIONS?