

Mechanical Ventilation of the Neonatal Foal

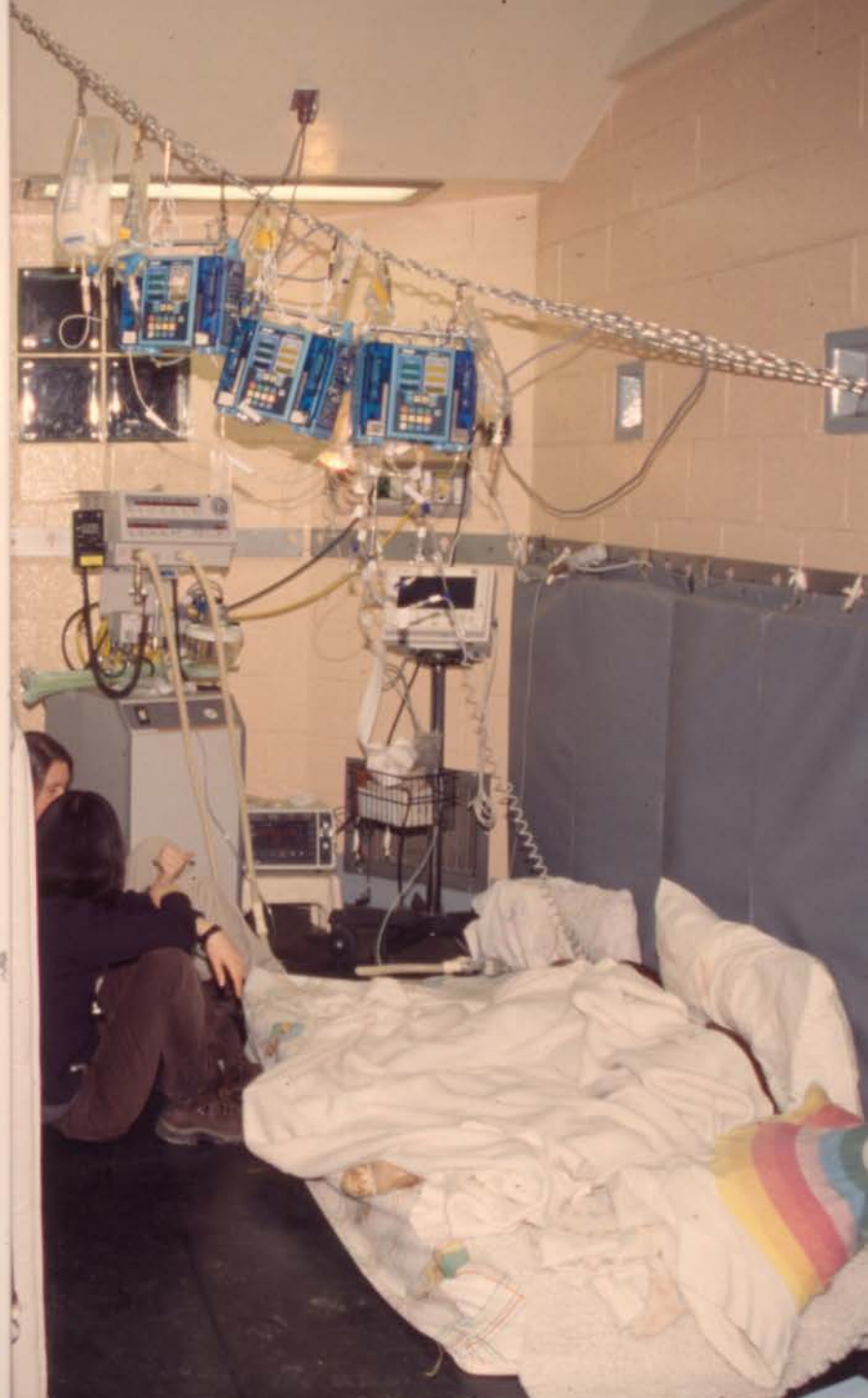


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Online Lecture Notes

PDF files of slides

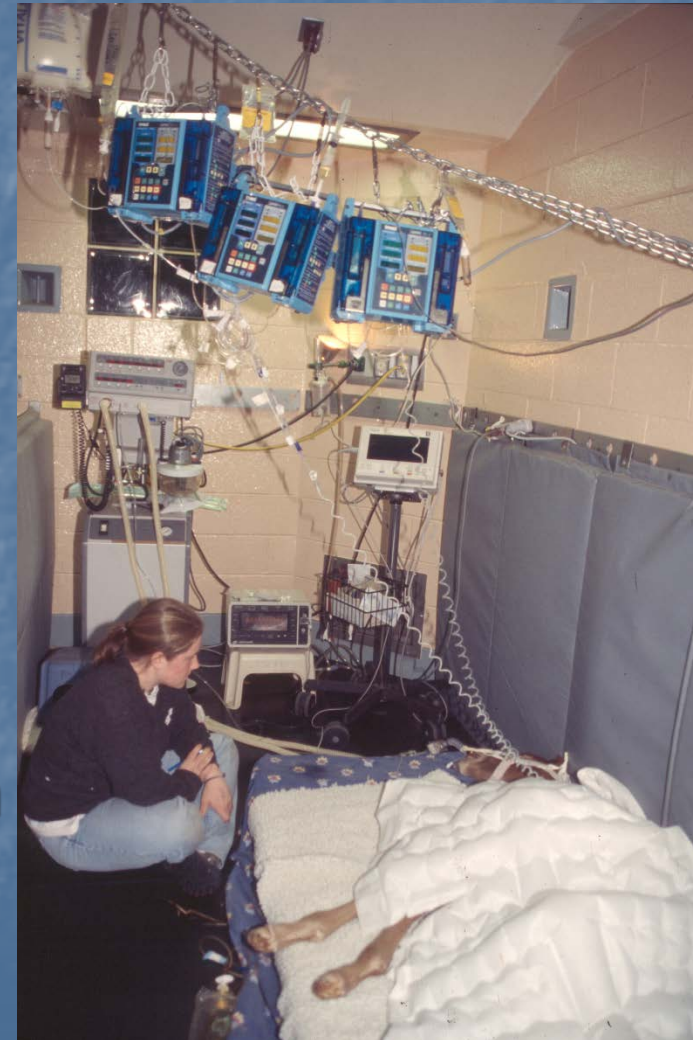
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Positive Pressure Ventilation Goals

- Pulmonary gas exchange
 - Support exchange
 - Allow manipulation V/Q matching
- Manipulate lung volume
 - Returning normal FRC
- Decrease work of breathing
 - Allow fatigued muscles to rest
 - Decrease O₂ and energy utilization
 - Redirect perfusion



Positive Pressure Ventilation

Clinical Indications

- Neonatal Encephalopathy
- Weakness
- Persistent pulmonary hypertension
- Acute respiratory failure
 - ARDS
 - Infectious pneumonia
 - Non-infectious pneumonia
- Upper airway obstruction
- Septic shock
- Neuromuscular disorders



Goal of Ventilation

Provide respiratory support while therapies for underlying cause of the acute event are initiated and allow time for recovery

Three cases



Case 1

- 50-day-old Morgan colt
- June 13
 - Normal in the morning
 - Evening found down in the field
 - Weak
- Rx
 - Intravenous fluids
 - Antibiotics
 - Tube fed milk
- June 14 6:00 a.m.
 - Respiratory distress
 - Cyanotic

Ventilation Case 1

- Admission Physical Exam
 - Weak, no eyelid tone
 - No tongue tone, weak tail tone
 - Shallow, rapid respiratory pattern
 - Mark nostril flare
- Therapy
 - Botulism antitoxin
 - Intravenous fluids
 - Intravenous ceftiofur sodium
 - Indwelling nasogastric tube
 - Ventilation



Case 1

	Adm	40 min	2 hr
pH	7.325	7.265	7.289
Pco ₂	56	68	70
Po ₂	40	229	243
SAT	64.5	99.7	99.7
HCO ₃	29.6	31.1	33.5
BE	+2.7	+2.6	+5.5
RA		10 lpm	10 lpm



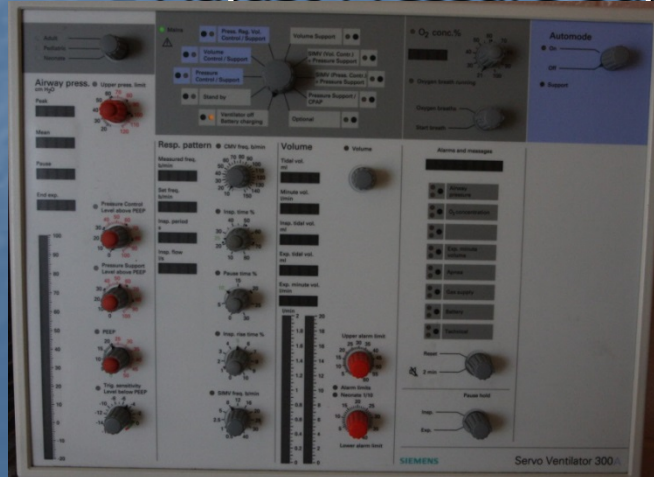
Pressure Support Ventilation (PSV)

- Partial ventilatory support
 - Assist flow-cycled mode
 - Support spontaneous breathing effort
 - Providing satisfactory oxygenation
 - Decreased the work of breathing
- Breathing controlled by foal
 - Inspiratory time
 - Inspiratory flow rate
 - Tidal volume
- Reduced work of breathing
- "Off-switch" value
 - 25% of the peak flow
 - Fixed low inspiratory flow rate



Pressure Support Ventilation New Millennium Ventilators

- Volume Support Ventilation (VSV)
- Adaptive Support Ventilation (ASV),
- Volume-Assured Pressure Support (VAPS)
 - Pressure support
 - Target volume – each breath, min volume
 - Breath to breath changes in parameters
 - Adjust Pressure Support to a volume goal



Positive End-Expiratory Pressure (PEEP)

Continuous Positive Airway Pressure (CPAP)

- PEEP
 - Positive pressure between ventilator breaths
- CPAP
 - Positive pressure throughout spontaneous respiration
- Physiologic effect
 - Increase functional residual capacity (FRC)
 - Decreases intrapulmonary shunting
 - Improve V/Q matching

PEEP/CPAP

- Ideal FRC – best compliance
- Ideal FRC – least airway resistance
 - Less atelectasis
- Cardiovascular effects
 - Excessive PEEP
 - Decrease cardiac return
 - Increase pulmonary Resistance
 - Depends on the lung compliance
 - Low compliance less transmitted to vessels
 - Hypovolemia – increase negative effect
- V/Q matching

Progressive Atelectasis



PEEP

- Full recruitment
 - Requires 15 to 20 minutes
 - PEEP does not recruit but stabilizes lung
 - Break in circuit – begin again
- Optimal PEEP
 - Maximum improvement pulmonary function
 - Minimal hemodynamic compromise
 - Inflection points on PV curves
 - PEEP/CPAP grid
 - Pao₂
 - Static Compliance
- Optimal PEEP is a balance
 - Holding open recruitable alveoli - diseased regions
 - Not overdistending alveoli - healthier lung

PATIENT DATA



AIRWAY PRESSURE

cmH₂O

MEAN AIRWAY PRESSURE

PEAK AIRWAY PRESSURE

PEEP/CPAP

PLATEAU PRESSURE

ASSIST

SPONTANEOUS

SIGH

PLATEAU

RATE/I:E

RATE bpm

I:E RATIO

liters

TIDAL VOLUME

MINUTE VOLUME

SPONT. MINUTE VOLUME

VENTILATOR SETTINGS

PEEP/CPAP



TIDAL VOL liters

SET RATE bpm

PEAK FLOW lpm

O₂%

TIDAL VOLUME

RESPIRATORY RATE

PEAK INSPIRATORY FLOW

7

8

9

SENSITIVITY

O₂%

PLATEAU

4

5

6

1

2

3

HIGH PRESSURE LIMIT

LOW INSPIRATION PRESSURE

LOW PEEP/CPAP PRESSURE

0

.

*

LOW EXHALED TIDAL VOL

LOW EXHALED MINUTE VOL

HIGH RESPIRATORY RATE

ENTER

CLEAR

CMV

SIMV

CPAP

++



100% O₂ SUCTION

MANUAL INSPIRATION

MANUAL SIGH

AUTOMATIC SIGH

NEBULIZER

VENTILATOR STATUS

HIGH PRESSURE LIMIT

LOW INSPIRATORY PRESSURE

LOW PEEP/CPAP PRESSURE

LOW EXHALED TIDAL VOLUME

LOW EXHALED MINUTE VOLUME

HIGH RESPIRATORY RATE

I:E

APNEA

LOW PRESSURE O₂ INLET

LOW PRESSURE AIR INLET

EXHALATION VALVE LEAK

LOW BATTERY

CAUTION

NORMAL

LAMP TEST

ALARM SILENCE

ALARM RESET

Adult
 Pediatric
 Neonate

Airway press. ● Upper press. limit
 cm H₂O

Peak
 Mean

Pause

End exp.

100
90
80
70
60
50
40
30
20
10
0
-10
-20

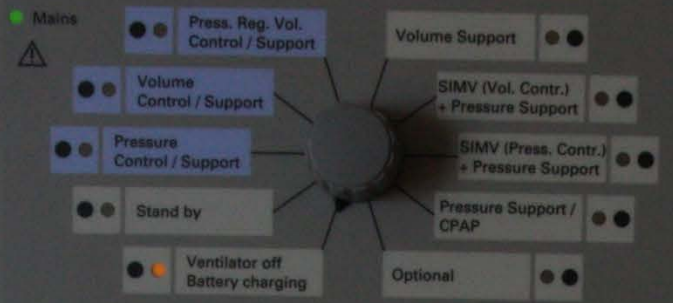
60 70 80
 50 40 30 20
 90 100 110 120

● Pressure Control
 Level above PEEP
 40 50 60 70
 30 20 10 0 100

● Pressure Support
 Level above PEEP
 40 50 60 70
 30 20 10 0 100

● PEEP
 20 25 30 35
 15 10 5 0 45 50

● Trig. sensitivity
 Level below PEEP
 -8 -6 -4 -2
 -10 -12 -14 0



Resp. pattern ● CMV freq. b/min

Measured freq. b/min
 Set freq. b/min

● Insp. time %
 40 50 60 70
 30 20 10 0 80

● Pause time %
 15 20 25 30
 10 5 0 30

● Insp. rise time %
 4 6 7 8 9
 3 2 1 0 10

● SIMV freq. b/min
 8 12 16 20 25 30
 5 2.5 1 0.5 40

Volume ● Volume

Tidal vol. ml
 Minute vol. l/min

Insp. tidal vol. ml
 Exp. tidal vol. ml

Exp. minute vol. l/min

I/min 2 1.8 1.6 1.4 1.2 1 0.8 0.6 0.4 0.2 0
 20 18 16 14 12 10 8 6 4 2 0

Upper alarm limit
 25 30 35 40 45 50 55 60

● Alarm limits
 ● Neonate 1/10
 15 20 25 30 35 40

Lower alarm limit

● O₂ conc. %
 50 60 70
 40 30 20 10 100

● Oxygen breath running
 Oxygen breaths
 Start breath

Automode
 ● On
 Off
 ● Support

Alarms and messages

Airway pressure
 O₂ concentration
 Exp. minute volume
 Apnea
 Gas supply
 Battery
 Technical

Reset
 2 min

Pause hold

Insp.
 Exp.

Ventilator Settings

- F_{iO_2}
- Tidal Volume
- Respiratory rate
- Trigger sensitivity
- Peak Flow
 - Inspiratory time
 - Inspiratory rise time
- Inspiratory pause
- PEEP/CPAP



Ventilator Settings

- Pressure Support
 - Target pressure
 - Level dependent on
 - Resistance and compliance of ventilator
 - Airway resistance
 - Lung compliance
 - Inspiratory effort
 - Absence of lung disease 8 – 12 cmH₂O
 - Low compliance as high as 20 – 25 cm H₂O
 - Higher PS helpful in patient-ventilator dyssynchrony
 - When inspiratory effort exceeds rate of gas delivery



No Sedation





Case 1

Ventilator Set Up

- Goals
 - Decrease work of breathing
 - Maintain FRC
- Mode: Pressure Support with CPAP
 - PS initially set at 9 cmH₂O
 - Normal lungs
 - CPAP initially set at 4 cmH₂O
 - Normal lungs
- Parameters set by foal
 - Tidal Volume = 5.6 – 6.2 ml/kg (7 ml/kg)
 - RR 32
 - PIP = 18-20 mmH₂O

Case 1

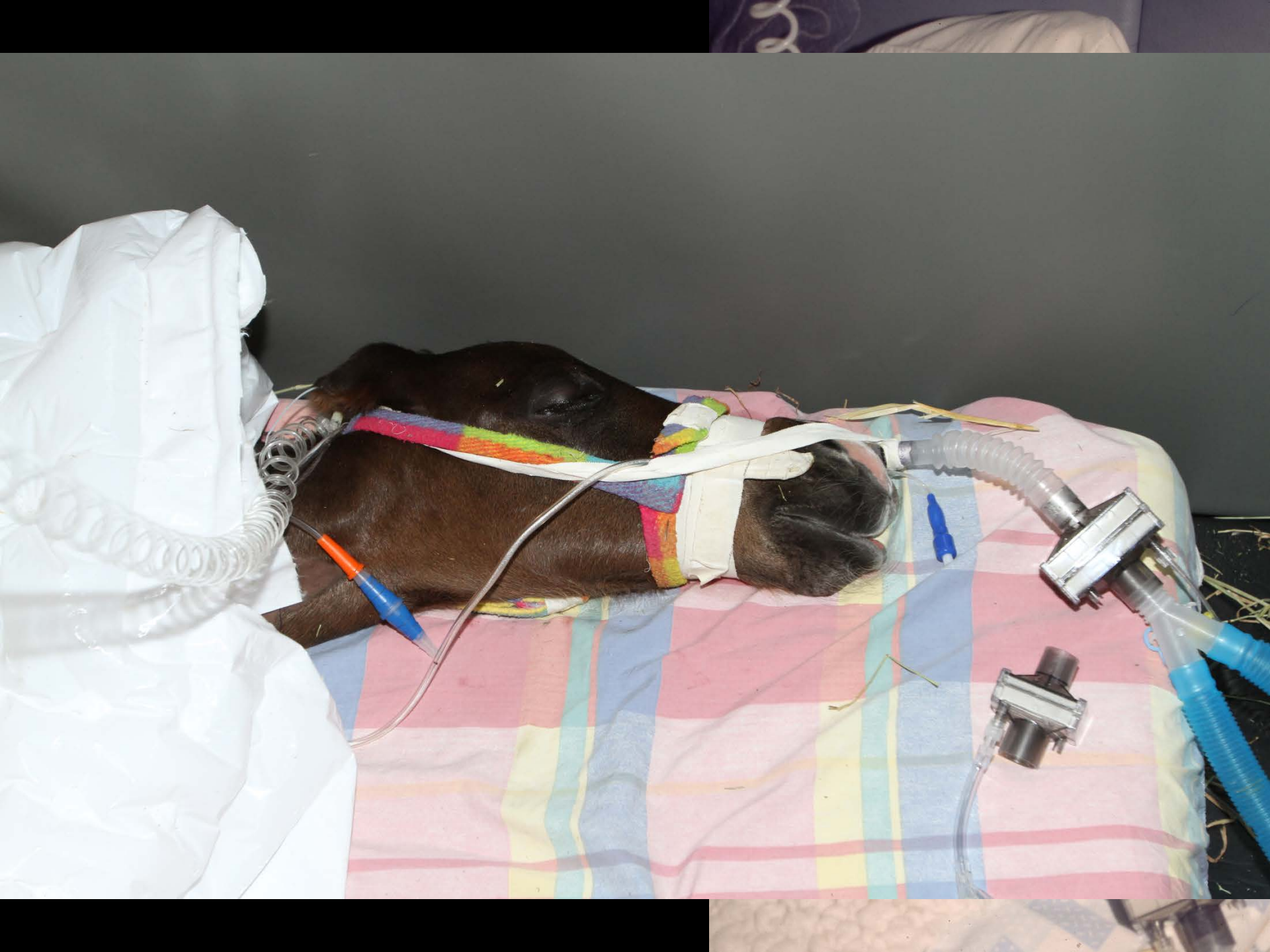
	7 hr	HD 2	HD 2	HD 7		
pH	7.393	7.385	7.396	7.414		
Pco ₂	53	51	51	48	mode	PS
Po ₂	97	74	127	114	TV	550-680
SAT	96.7	92.8	98.4	98.4	RR	32 – 26
Cont		17	17.4	17.1	PIP	20 – 18
HCO ₃	32	31	31	31	P _{Plat}	20 – 18
BE	+6.5	+5.2	+6.0	+6.0		
FIO ₂	0.3	0.3	0.4	0.3		
PEEP	4	4	5	5		
ETCO ₂	53	48	49	48		
PS	9	11	11	11		



Ventilator Settings

- All ventilator settings
 - Adjusted dynamically
 - Success dependent on tailoring to the individual
- Monitor
 - Pulmonary mechanics
 - ETCO_2
 - Airway pressures
 - Clinical status
 - ABG determinations





Case 1

Problems

- $\text{ETCO}_2 = 0$
- Long inspiration
- Flow meter shows a dramatic \downarrow TV
- Common problem
 - Have foal sitter monitor cuff
 - Often slow leak
 - Bad valve – use hemostat or clamp
 - Leaking cuff – replace endotracheal tube



Case 1

	HD 9	HD 9
pH	7.304	7.443
Pco ₂	76	52
Po ₂	115	111
SAT	97.5	98
Cont	16.0	16.3
HCO ₃	38	36
BE	+9.6	+10.8
FIO ₂	0.35	0.35
ETCO ₂	72	52
Mode	PS	PS
PS	20	12





Weaning from Ventilation

- When?
 - Consider as soon as begin ventilation
 - Goal: keep ventilation period short
- Indications
 - Cardiovascular stability
 - Metabolic stability
 - Sepsis Controlled
 - Original problem has resolved/improved
- No reliable predictor foal is ready



Case 1

Weaning

- 1st weaning challenge HD 6
 - Off the ventilator
 - Good breathing efforts
 - ETCO₂ increased
 - Foal became cyanotic (on INO₂)
 - Aerophagia - increased abdominal size
 - 10 minute trial
- 2nd weaning trial HD 8
 - After 22 minutes Paco₂ 48 → 60



3rd Weaning Attempt

	HD 10	3 pm	6 pm	3 am	6 am	HD 14
pH	7.443	7.365	7.394	7.338	7.031	7.420
Pco ₂	52	55	50	64	129	49
Po ₂	111	72	184	79	49	120
SAT	98	91	99	92	60	98
HCO ₃	36	32	31	34	34	32
BE	+10.8	+5.4	+5.5	+6.7	-1.3	+7.0
FIO ₂	0.35	8 lpm	10 lpm	8 lpm	0.5	4 lpm
ETCO ₂	52				84	
Mode	PS	off	off	off	PS	off

Outcome

- Successful weaning HD 14
- Standing day 15
- Dysphagia
 - HD 22 – able to swallow water
 - HD 23 – able to swallow solids
- Hospital Discharge HD 30



Case 2



Case 2

Clinical Problems

- Septic Shock
- Bacteremia/Sepsis
 - *Pantoea agglomerans*
- Neonatal Encephalopathy
 - Somnolent, Facial nerve paresis
 - Seizure-like activity
- Neonatal Enteropathy
 - Fetal diarrhea, dysmotility
- Neonatal Nephropathy
- Other problems
 - Urachitis, hepatomegaly
 - Linear dermal necrosis, patent urachus
 - Angular limb deformity



Case 2

	Adm	1 hr
pH	7.339	7.349
Pco ₂	60	58
Po ₂	44	144
SAT	77	100
Cont	13	15
HCO ₃	32	32
BE	+5.6	+5.9
INO ₂	RA	10 lpm



Neonatal Encephalopathy

- *4 hours*
 - *Respiratory effort decreased*
 - *Apneustic breathing (breath holding)*



Case 2

Neonatal Encephalopathy

- *10 hours*
 - *Apneic respiratory pattern*
 - *40 second apneic period*
 - *Cluster breathing in-between*



Case 2

Neonatal Encephalopathy

- *12 hours*
 - *Periods of somnolence and nonresponsiveness*
 - *Apneic respiratory pattern with cluster breathing*
 - *Facial nerve paresis*
 - *Right ear lower and slower to respond*
 - *Ears are not synchronized*
- *21 hours*
 - *Seizure-like activity*
 - *Opisthotonus*
 - *Tonic/Clonic marching activity*
 - *Treated with intravenous phenobarbital*

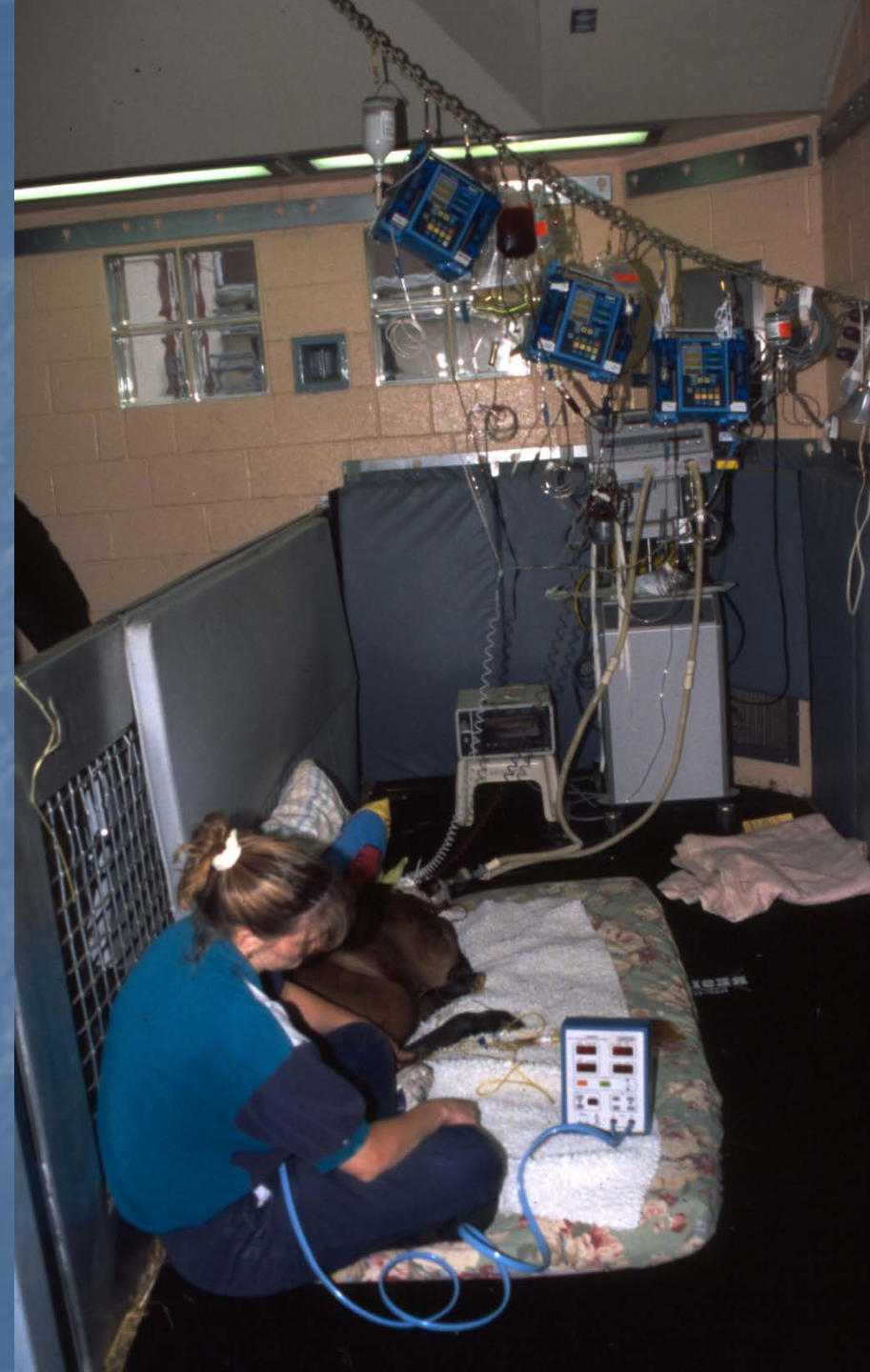
Case 2

	27 hr	29 hr
pH	7.313	7.269
Pco ₂	75	85
Po ₂	118	119
SAT	100	100
Cont	14.5	14.7
HCO ₃	38	39
BE	+10.4	+10.3
INO ₂	10 lpm	10 lpm



Ventilate

- Goals
 - Increase alveolar ventilation
 - Maintain FRC
- Mode: IMV/PS with PEEP/CPAP
 - TV = 460 ml (8.5 ml/kg)
 - PIP = 18 cmH₂O
 - PS initially set at 9 cmH₂O
 - Normal lungs
 - PEEP/CPAP = 4 cmH₂O
 - Normal lungs
 - Peak flow = 60 lpm
 - RR = 24
 - Foal's rate 33
 - FIO₂ = 0.4



Case 2

	27 hr	29 hr	31 hr	36 hr		
pH	7.313	7.269	7.353	7.428	mode	SIMV
Pco ₂	75	85	67	50	TV	460 ml
Po ₂	118	119	96	164	PF	60
SAT	100	100	99	100	RR	38
Cont	14.5	14.7	13.9	14.4	PEEP	4
HCO ₃	38	39	38	33	PS	9
BE	+10.4	+10.3	+10.9	+8.3	P _{peak}	24
FiO ₂	10 lpm	10 lpm	0.4	0.5	P _{plat}	18
ETCO ₂			54	46		

Weaning

- Began asking when? within 12 hours
- After 21 hours – PS trial

Case 2

	48 hr	52 hr	57 HR	60 hr	48 hr	52 hr
pH	7.447	7.473	7.392	mode	SIMV	PS/CPAP
Pco ₂	45	40	54	TV	460 ml	520-75
Po ₂	242	91	252	PF	60	
SAT	100	100	100	RR.7	36	22
Cont	14.5	14.1	14.3	PEEP	4	4
HCO ₃	31	29	33	PS	9	6
BE	+7.2	+6.0	+7.7	P _r peak	21	
FIO ₂	0.5	0.35	10 lpm	P _r plat	16	
ETCO ₂	42	38				



Case 3 Septic Shock



Case 3

- Admission - 8 hr old
- Septic shock - *Streptococcus* bacteremia
 - Minimally responsive
 - Hypothermic (36.8 C)
 - Hypotonia
 - Pupils were pinpoint, iris edema
 - Inappropriately low heart rate
 - Cold legs, and poor peripheral perfusion
- Admission lab work
 - Leukopenic (WBC = 528 cells/ul)
 - Hypoglycemia – required 20 mg/kg/min to get > LO

Case 3 Therapy

- Intranasal oxygen
- Shock doses of fluids
- Plasma
- Antimicrobials
- Ventilation
- Dobutamine
- Norepinephrine

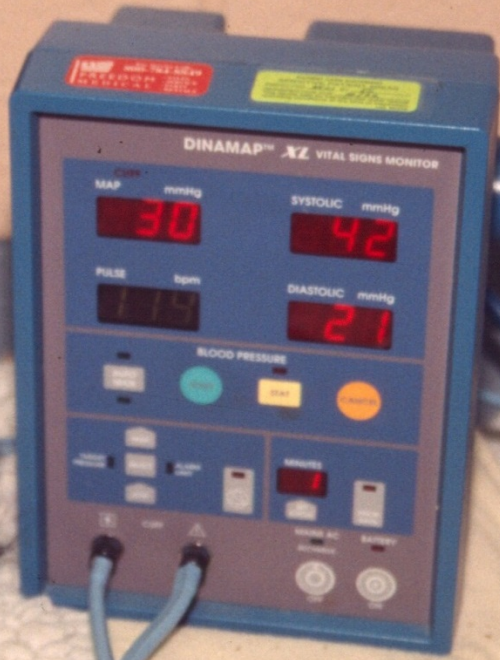


Benefits of Mechanical Ventilation

- Traditional
 - Improve gas exchange
 - Improve V/Q matching
 - Decrease shunt fraction
- Benefit of decreasing work of breathing
 - Normal quiet breathing
 - Inhalation active process
 - Requires energy
 - 3% - 5% O₂ consumed
 - Exhalation is a passive
 - Requires no energy, O₂

Benefits of Mechanical Ventilation

- Pulmonary failure 2ndary to septic shock
 - Respiratory distress
 - Work of breathing
 - O_2 required up to 50% of available O_2
 - Diverts perfusion resources
 - Accessory muscles recruited
- Relieving work of breathing
 - Redistribution of O_2
 - Redistribution of perfusion
 - Sparing energy resources
- Ventilation foals with septic shock
 - Improve perfusion, increase BP
 - Improved glucose balance



3M MALLORY WATSON
DINAMAP XZ VITAL SIGNS MONITOR

CAUTION
DO NOT OPEN
FRONT PANEL
UNLESS
INSTRUCTED
BY A
QUALIFIED
TECHNICIAN

DINAMAP™ XZ VITAL SIGNS MONITOR

MAP mmHg

30

SYSTOLIC mmHg

42

PULSE bpm

115

DIASTOLIC mmHg

21

BLOOD PRESSURE

START

STOP

POWER

TEST

MODE

MODE

MODE

1

MODE

MODE

MODE

MODE

MODE

MODE

MODE

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Case 3



Ventilate

- Goals
 - Decrease the work of breathing
 - Correct pulmonary hypertension
 - Maintain FRC
- Initial settings
 - Mode: PS with CPAP
 - PS initially set at 18 cmH₂O
 - Based on ease of breathing and resulting TV
 - PEEP/CPAP = 8 cmH₂O
 - FIO₂ = 1.0
- Set by foal
 - TV = 180 ml (7 ml/kg)
 - PIP = 32 cmH₂O
 - RR = 48



Case 3

	Adm	1 hr	1.5 hr	Mode	PS
pH	7.220	7.072	7.073	TV	180
Pco ₂	65	70	62	RR	48
Po ₂	22	20	248	PEEP	8
SAT	27.7	21.2	99.6	PS	18
Cont	5.1	3.4	14.9	P _{peak}	32
HCO ₃	27	20	18		
BE	-1.7	-9.6	-11.3	NO	20 ppm
FIO ₂	0.21	1.0	1.0		

Case 3

	3.75 hr	4 hr	5 hr	6 hr	Mode	PS
pH	7.000	7.062	7.089	7.061	TV	220
Pco ₂	96	92	84	98	RR	45
Po ₂	73	25	146	96	PEEP	10
SAT	86.3	29.4	97.8	92.3	PS	24
Cont	11.4	4.1	14.1	13.2	P _{peak}	35
HCO ₃	24	26	26	28		
BE	-7.5	- 4.6	- 4.6	- 3.1	NO	20 ppm
FIO ₂	1.0	1.0	1.0	0.50		

Case 3

- Multifocal necrotizing interstitial pneumonia

