GENERALIDADES DE LA VENTILACION MECÁNICA EN PEDIATRÍA

KLGO. JOSÉ MAURICIO LANDEROS
HOSPITAL DE NIÑOS ROBERTO DEL RÍO
KINESIOLOGÍA UNIVERSIDAD SAN SEBASTIÁN

HOSPITAL ROBERTO DEL RIO

UNIVERSIDAD SAN SEBASTIAN

1

2

- Preferencia por modos de Controlados por Presión y modos duales controlados por volumen pero limitados por presión

DPA/SDRA

Estrategias Protectoras:
PC: PIM < 35 cmH2O/ FR < 35 rpm

VCRP: Vt para Pplat < 30 cmH2O

Am J Respir Crit Care Med Vol 182. pp 1465–1474, 2010

3

JOURNAL OF LAPAROENDOSCOPIC & ADVANCED SURGICAL TECHNIQUES
Volume 21, Number 7, 2011

DOI: 10.1089/lap.2011.0051

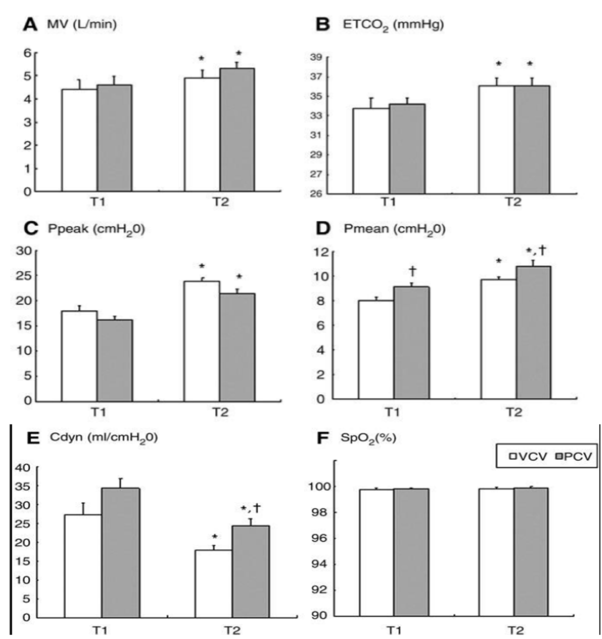
Full Report: Pediatrics

Effect of Pressure- Versus Volume-Controlled Ventilation on the Ventilatory and Hemodynamic Parameters During Laparoscopic Appendectomy in Children: A Prospective, Randomized Study

Ji Young Kim, MD,[1,2] Cheung Soo Shin, MD,[1,2] Kyung Cheon Lee, MD,[3]
Young Jin Chang, MD,[3] and Hyun Jeong Kwak, MD[3]

TABLE 2. THE CHANGES OF HEMODYNAMIC PARAMETERS DURING LAPAROSCOPIC APPENDECTOMY

	VCV (n=17)		*PCV* (n=17)	
	T1	*T2*	*T1*	*T2*
SBP (mmHg)	102±15	113±14[a]	106±9	108±28
MBP (mmHg)	77±12	88±14[a]	77±8	91±13[a]
DBP (mmHg)	59±16	69±13[a]	56±9	71±13[a]
HR (beats/min)	101±16	100±16	91±13	91±15



4

Am J Respir Crit Care Med. 2018 Nov 1;198(9):1199-1207. doi: 10.1164/rccm.201705-0989OC.

Airway Pressure Release Ventilation in Pediatric Acute Respiratory Distress Syndrome. A Randomized Controlled Trial.

Lalgudi Ganesan S[1], Jayashree M[1], Chandra Singhi S[1,2], Bansal A[1].

APRV

- Unicéntrico
- SDRAP
- PEEP ALTA según Presión Plateau (+1 a 2 cmH2O)
  - Ajustada para Vt 6-7 ml/kg peso ideal
  - 15-20 si PaFi > 200
  - 20-25 si PaFi > 100
  - 25-30 si PaFi < 100
- PEEP BAJA 0 cmH2O
- Tiempo de PEEP ALTA 4 segundos
- Tiempo de PEEP BAJA determinada según flujo espiratorio (75% FEP)

VMC

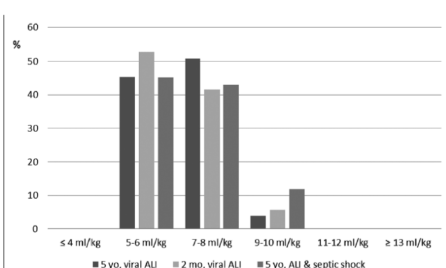
- Ventilación protectora
- Vt bajos
- Hipercapnia permisiva

Mortalidad a los 28 días:
APRV 53,8 % v/s VMC 26,9 %

5

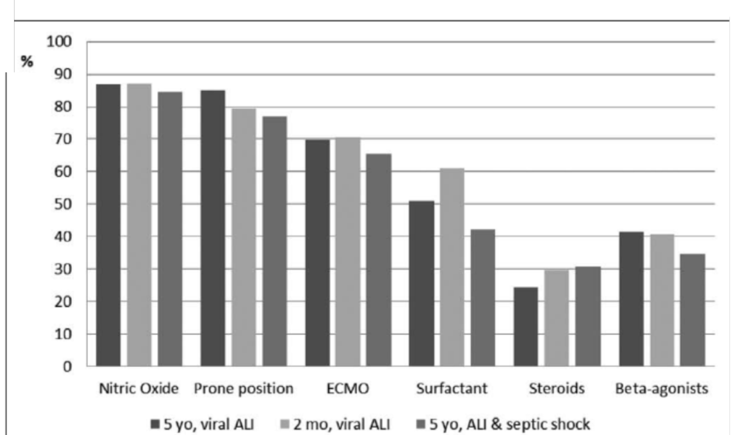
Mechanical Ventilation Strategies in Children With Acute Lung Injury: A Survey on Stated Practice Pattern*

Miriam Santschi, MD[1]; Adrienne G. Randolph, MD[2]; Peter C. Rimensberger, MD[3]; Philippe Jouvet, MD[4]; for the Pediatric Acute Lung Injury Mechanical Ventilation (PALIVE) Investigators, the Pediatric Acute Lung Injury and Sepsis Investigators Network (PALISI), and the European Society of Pediatric and Neonatal Intensive Care (ESPNIC)



yo: year old, mo: month old, ALI: acute lung injury.

Vt



yo: year old, mo: month old, ALI: acute lung injury

Terapias asociadas

6

Published in final edited form as:
Pediatr Crit Care Med. 2017 November ; 18(11): 1019–1026. doi:10.1097/PCC.0000000000001305.

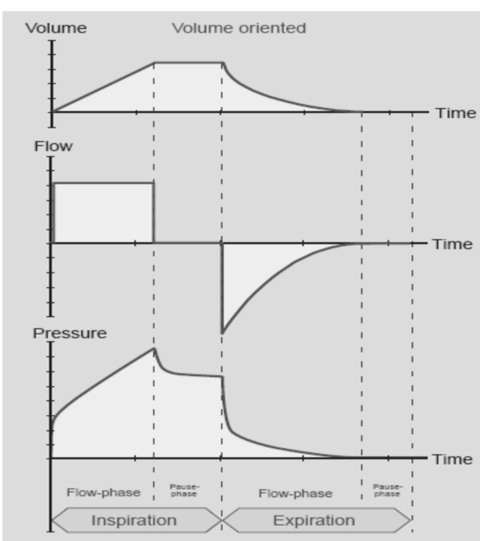
Association of Response to Inhaled Nitric Oxide and Duration of Mechanical Ventilation in Pediatric Acute Respiratory Distress Syndrome

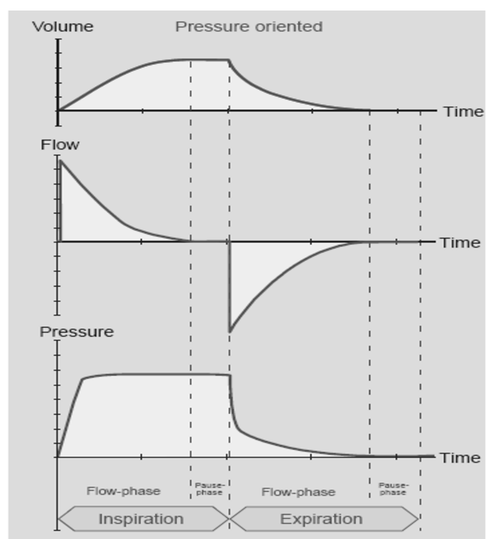
Jasmine C. Dowell, MD[1], **Neal J. Thomas, MD, MSc**[2], and **Nadir Yehya, MD**[1]

Cohorte Retrospectiva
161 niños en VM e instalación de iNO desde 1 hora a 3 días del inicio del SDRAP

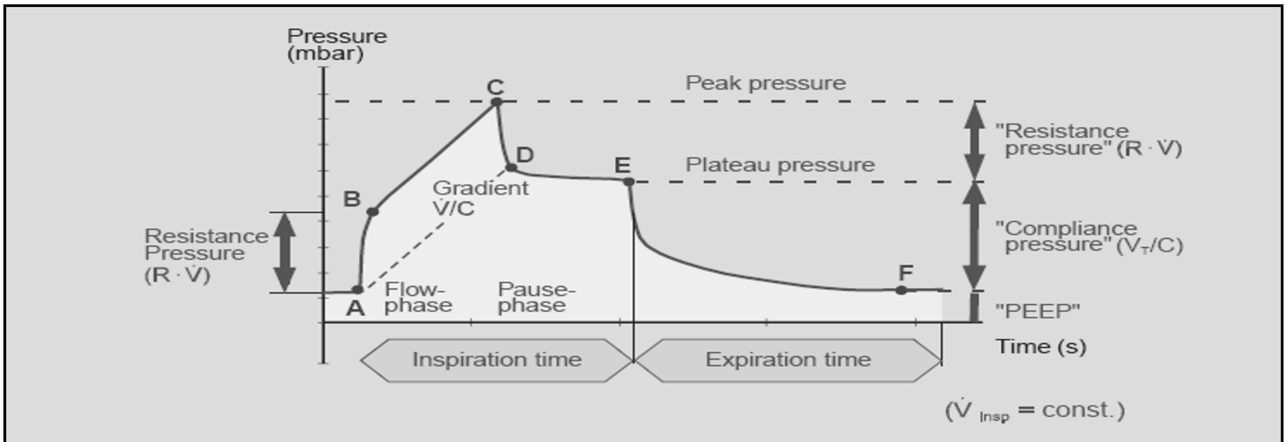
Outcomes	Todos	Respondedores	No Respondedores	
ECMO	17 (11)	6 (6)	11 (17)	0.034
Ventilator days (all)	13 [8, 23.5]	10 [7, 20]	16 [10, 39]	< 0.001
Ventilator days (survivors)	14 [9, 25]	11 [8, 20]	17.5 [13, 44]	< 0.001
PICU/hospital deaths (%)	34 (21)	21 (21)	13 (21)	0.999

7





8



$R_{insp} = (PIP - P_{plat})$ / Flujo Inspiratorio

$D_{est} = V_t / (P_{plat} - PEEP)$

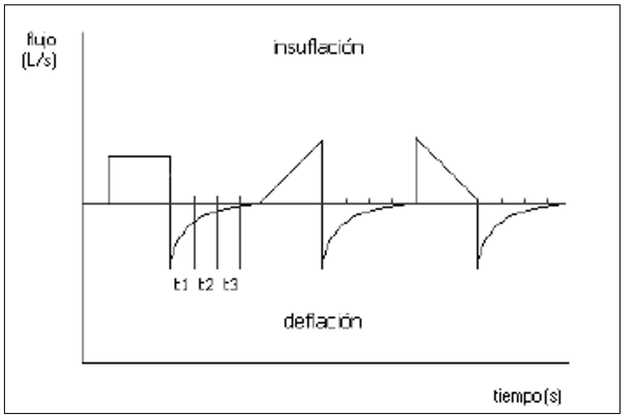
9

Programación

RNPT PEG:	0.25-0.55
RNT	: 0.50-0,70
Lactantes	: 0.60-0,90
Niños	: 0,80-1.20

- **T_{insp}: a > edad > T_{insp}**
- **Ajustar según patrón respiratorio.**
- **Usualmente se intenta mantener al menos un T_{insp} del 30-33% del T_{tot}**
- **Ajustar según τ (C x R): tiempo necesario para vaciar el 63 % del volumen pulmonar**

10



- La deflación es un proceso pasivo
- Se considera como curva exponencial:
  La declinación del flujo inicial se puede estimar como 1/e (e=2,718281828459…)

11

	% de flujo inicial	% de volumen espirado
$\tau\, 0 =$	100	0
$\tau\, 1 = 1/e =$	36,7	63,3
$\tau\, 2 = (1/e)(1/e) =$	13,5	86,5
$\tau\, 3 = (1/e)(1/e)(1/e) =$	4,9	95,1

Tiempo Inspiratorio/Espiratorio: al menos 3 τ

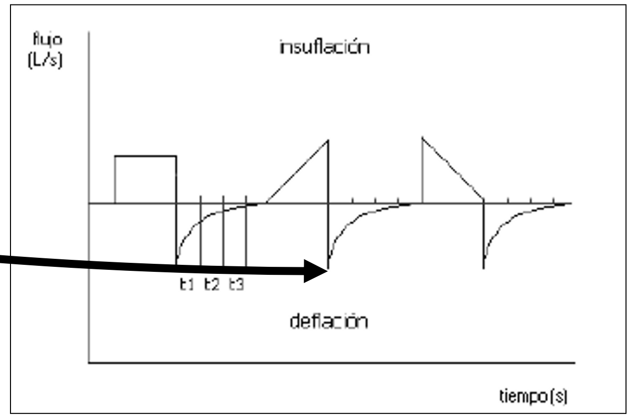
R_{insp}= (PIP-PPlat) / F_{insp} x D_{est} = V_t / (PPlat-PEEP)

R_{esp}= (Pplat - PEEP)/ F_{esp}

12

R_{esp}= (Pplat - PEEP)/ F_{esp}

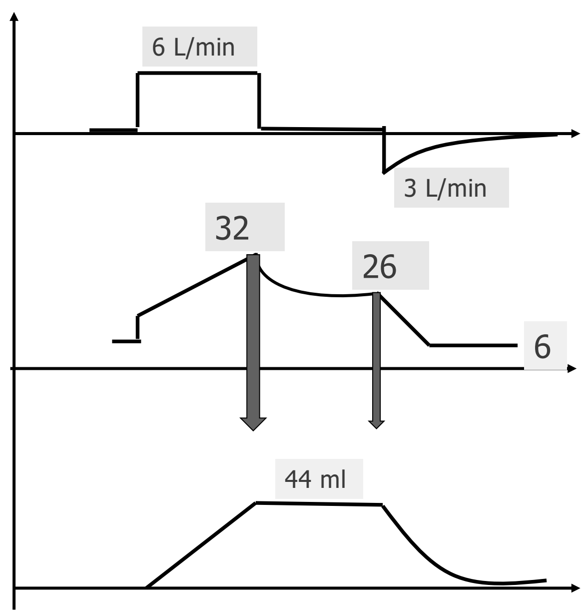
RETRACCIÓN ELÁSTICA



13

Algunos cálculos

- Para los siguientes resultados de un tiempo de pausa inspiratorio:
- Calcule Rinsp; Resp; Dest; Ti; Te; I:E; FR



14

¿Cómo se hace?

1º Realizar los cálculos básicos

- R Insp = (PIM – P Plateau) / Flujo Inspiratorio
- Distensibilidad = Vt / (P Plateau – PEEP)
- R esp = (P Plateau – PEEP) / Flujo Espiratorio

2° Calcular las constantes de tiempo

- τ_{insp} = Distensibilidad x Resistencia Inspiratoria
- τ_{esp} = Distensibilidad x Resistencia Espiratoria

τ_{esp} = Distensibilidad x Resistencia Espiratoria

$$= \frac{Vt}{\cancel{DP}} \cdot \frac{\cancel{DP}}{Fesp} = \frac{Vt}{Fesp}$$

15

3° Calcular Ti y Te

- Ti = τ_{insp} x 3
- Te= τ_{insp} x 3

4° Cálculo de la Frecuencia Respiratoria

- Calcular Tiempo Total del ciclo ventilatorio

  TTC = Ti + Te

- Calcular la Frecuencia respiratoria

  FR = 60 / TTC

5° Relación I:E =T esp / T insp

16

Intensive Care Med (2009) 35:1428–1437
DOI 10.1007/s00134-009-1527-z

PEDIATRIC ORIGINAL

Robinder G. Khemani
David Conti
Todd A. Alonzo
Robert D. Bart III
Christopher J. L. Newth

Effect of tidal volume in children with acute hypoxemic respiratory failure

Table 1 Univariate analysis by survival

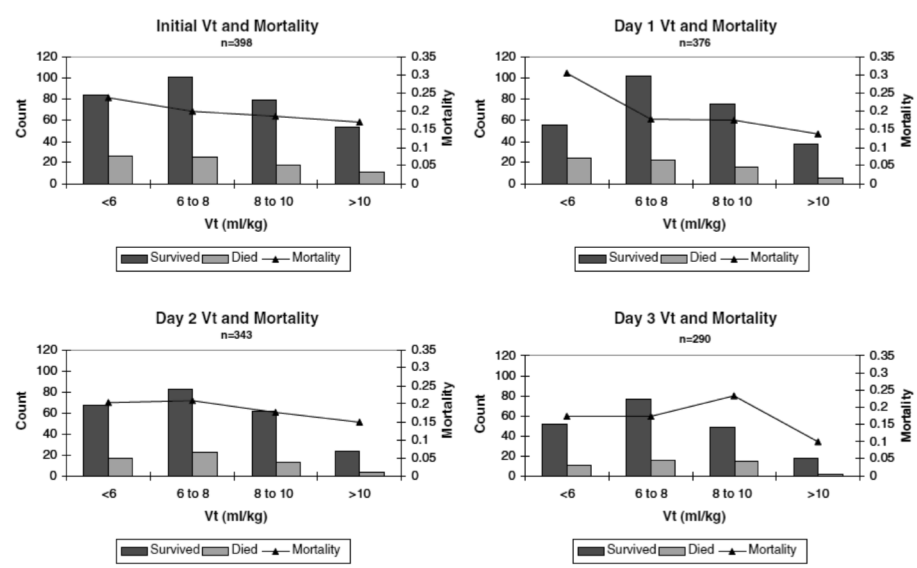
	All $n = 398$	Survived $n = 318$	Died $n = 80$	*P* value
Weight (kg)	16 (8, 36)	15 (9, 34)	17 (8, 44)	0.73
Age (years)	4.3 (1, 11.5)	3.9 (1, 10.9)	5.9 (0.8, 12.5)	0.73
Race				
Latino	194 (48.7)	157 (49.4)	37 (46.3)	0.71
White	74 (18.6)	56 (17.6)	18 (22.5)	0.40
Black	45 (11.3)	35 (11)	10 (12.5)	0.86
Other	85 (21.4)	70 (22)	15 (18.8)	0.63
Male	227 (57)	180 (56.6)	47 (58.8)	0.83
CXR bilateral infiltrates	192 (48.2)	148 (46.5)	44 (55)	0.22
PRISM Probability of death	0.57 (0.26, 0.86)	0.49 (0.22, 0.79)	0.87 (0.56, 0.97)	<0.001
Admission diagnosis				OR (95% CI)
Parenchymal lung disease[a]	117 (29.4)	92 (28.9)	25 (31.3)	Reference
Other respiratory disease	30 (7.5)	23 (7.2)	7 (8.8)	1.47 (0.57, 3.81)
Shock or sepsis	43 (10.8)	29 (9.1)	14 (17.5)	2.33 (1.08, 5.04)
Trauma	16 (4)	12 (3.8)	4 (5)	1.61 (0.48, 5.41)
Neurologic compromise	50 (12.6)	37 (11.6)	13 (16.3)	1.70 (0.79, 3.65)
Metabolic/renal disease	24 (6)	22 (6.9)	2 (2.5)	0.44 (0.10, 1.99)
Other diagnosis	28 (7)	21 (6.6)	7 (8.8)	1.61 (0.62, 4.20)
Gastrointestinal diagnosis	61 (15.3)	53 (16.7)	8 (10)	0.73 (0.31, 1.73)
Orthopedic diagnosis[b]	29 (7.3)	29 (9.1)	0 (0)	0 (0, 0.27)

Continuous variables expressed as median and interquartile range. Categorical variables expressed as count and percentage

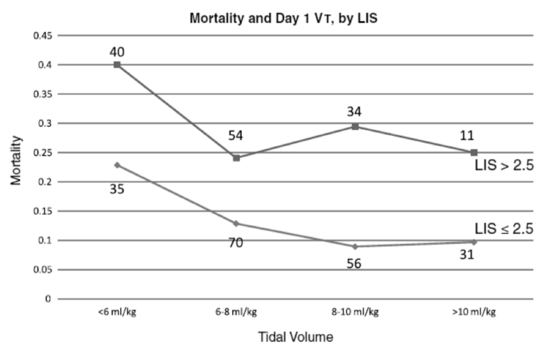
[a] Parenchymal lung disease used as baseline group for computation of odds ratios for diagnostic category for admission
[b] Orthopedic diagnosis was primarily scoliosis

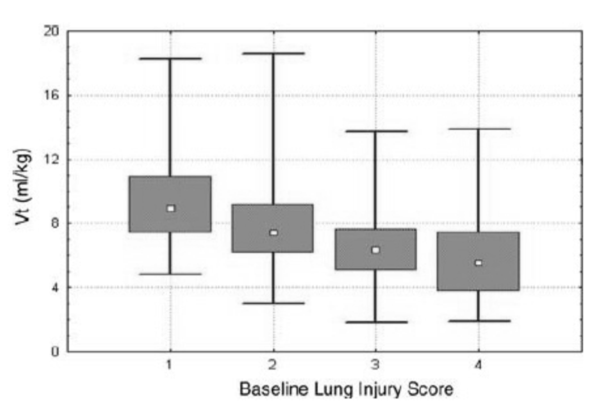
- 90 % ventilados en modos PC

17



18





Mortalidad, Vt y Score de Daño Pulmonar

19

Revisiones sinópticas basadas en la evidencia

- http://pedsccm.org/view-review.php?id=982

Reviews SYSTEMATIC REVIEW

Criteria abstracted from The Users' Guides to the Medical Literature series in JAMA

*Tidal Volume and Mortality in Mechanically Ventilated Children: A Systematic Review and Meta-Analysis of Observational Studies.

de Jager P, Burgerhof JG, van Heerde M, Albers MJ, Markhorst DG, Kneyber MC Crit Care Med 2014 42; 2461-72

Abstract

Review by: Gina Kim MD MPH, Children's Hospital Los Angeles, Los Angeles CA

Review Posted: 2016-02-24

20

	Albuali et al	Erickson et al	Flori et al	Halbertsma et al	Hu et al	Khemani et al	Khilnani et al	Silva et al
Number of patients	164	117	328	96	461	398	143	49
V_t for analysis	Expiratory	Calculated	Calculated	Unknown	Expiratory	Calculated	Expiratory	Expiratory
Mortality (%)	35; 21*	35	22	14	42	20	23; 37*	35

*These studies compared outcomes before and after lung-protective ventilation strategies.

Comparison Groups	Odds Ratio (95% CI)
V_t < 7 mL/kg vs. V_t > 7 mL/kg	1.04 (0.61, 1.76)
V_t < 8 mL/kg vs. V_t > 8 mL/kg	0.88 (0.56, 1.40)
V_t < 10 mL/kg vs. V_t > 10 mL/kg	0.83 (0.50, 1.37)
V_t < 12 mL/kg vs. V_t > 12 mL/kg	0.95 (0.36, 2.48)
V_t < 7 mL/kg vs. V_t > 10 mL/kg	1.13 (0.44, 2.9)
V_t < 7 mL/kg vs. V_t > 12 mL/kg	1.02 (0.23, 4.53)
V_t < 8 mL/kg vs. V_t > 10 mL/kg	0.87 (0.44, 1.73)
V_t < 8 mL/kg vs. V_t > 12 mL/kg	0.90 (0.23, 3.61)

21

VAFO

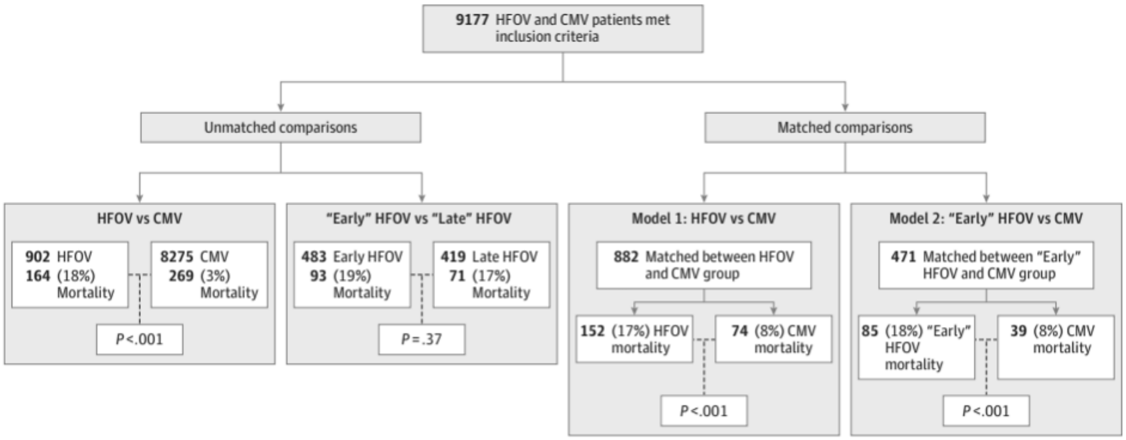
- Cambio de terapia de rescate a una terapia precoz (IOx > 15)

22

Original Investigation

Comparison of High-Frequency Oscillatory Ventilation and Conventional Mechanical Ventilation in Pediatric Respiratory Failure

Punkaj Gupta, MBBS; Jerril W. Green, MD; Xinyu Tang, PhD; Christine M. Gall, DrPHc; Jeffrey M. Gossett, MS; Tom B. Rice, MD; Robert M. Kacmarek, PhD, RRT; Randall C. Wetzel, MBBS

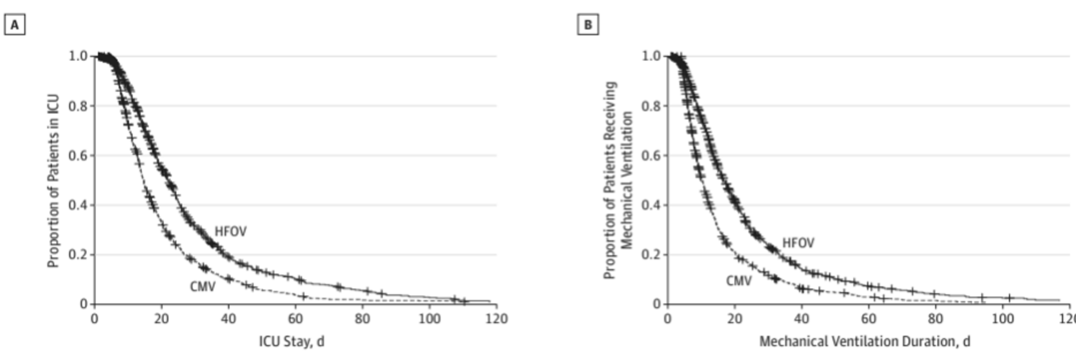


CMV indicates conventional mechanical ventilation; HFOV, high-frequency oscillatory ventilation.

JAMA Pediatr. 2014;168(3):243-249. doi:10.1001/jamapediatrics.2013.4463
Published online January 20, 2014.

23

Figure 2. Kaplan-Meier Curves for Intensive Care Unit (ICU) Length of Stay (LOS) and Duration of Mechanical Ventilation



A — No. at risk

	0	20	40	60	80	100	120
HFOV	882	420	125	60	30	13	4
CMV	882	267	75	24	11	9	5

B — No. at risk

	0	20	40	60	80	100	120
HFOV	882	307	88	39	18	10	5
CMV	878	166	44	18	8	3	3

24

Risk Factors for Mortality and Outcomes in Pediatric Acute Lung Injury/Acute Respiratory Distress Syndrome*

Flávia F. Panico, MD[1]; Eduardo J. Troster, PhD[2,3]; Cindy S. Oliveira, MD[4]; Aline Faria, MD[4]; Michelle Lucena, MD[5]; Paulo R. D. João, MD[5]; Everardo D. Saad, MD[6]; Flávia A. K. Foronda, PhD[1]; Artur F. Delgado, PhD[1]; Werther Brunow de Carvalho, PhD[1]

TABLE 4. Association Between Potential Predictive Variables and Mortality, Including the Airway Pressure Gradient on Day 1 in the Model

Variable	Multivariate OR (95% CI)	*p* for Multivariate Analysis
No. of organ dysfunctions at admission	2.08 (1.20–3.60)	0.009
Pediatric Risk of Mortality score	1.01 (0.92–1.10)	0.857
Airway pressure gradient on day 1	1.13 (1.00–1.28)	0.042

OR = odds ratio.

TABLE 5. Association Between Predictive Variables and Mortality, Including the Peak Inspiratory Pressure on Day 1 and the Airway Pressure Gradient on Day 1 in the Model

Variable	Multivariate OR (95% CI)	*p* for Multivariate Analysis
No. of organ dysfunctions at admission	2.16 (1.27–3.67)	0.005
Peak inspiratory pressure on day 1	1.13 (1.03–1.25)	0.010
Airway pressure gradient on day 1	1.09 (0.96–1.23)	0.178

OR = odds ratio.

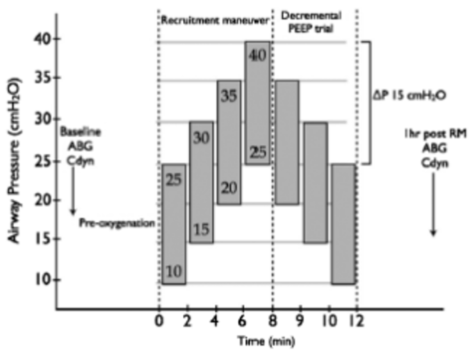
Pediatr Crit Care Med 2015; 16:e194–e200

25

RECOMENDACIONES PARA LA PEEP

- En SDRAP moderado con PEEP < 10: SpO2 92%-95%
- En SDRAP severo con PEEP optimizado >10: SpO2 88%-92%
- En SDRAP moderado a severo, considerar hipercapnia permisiva para minimizar el Daño Pulmonar Inducido por la Ventilación Mecánica (pH 7,2-7,30)

26



Pediatric Pulmonology 48:1135–1143 (2013)

Respiratory and Hemodynamic Effects of a Stepwise Lung Recruitment Maneuver in Pediatric ARDS: A Feasibility Study

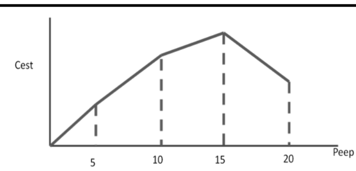
Pablo Cruces, MD,[1,2] Alejandro Donoso, MD,[1,2] Jorge Valenzuela, CRRT,[1] and Franco Díaz, MD[1,2,3*]

TABLE 2—Ventilatory Parameters at Baseline and 1 hr After RM (RM-1 hr)

	Baseline	RM-1 hr	
PaO_2/FIO_2, median (IQR)	117 (96–139)	164 (141–197)	$P < 0.01$
$PaCO_2$ (mmHg), median (IQR)	57 (41–66)	54 (39–66)	$P = 0.4$
C_{dyn} (ml/cmH_2O/kg), median (IQR)	0.48 (0.41–0.68)	0.6 (0.49–0.80)	$P < 0.01$
V_T (mL), mean ± SD	8.2 ± 2.5	9.6 ± 2.5	$P < 0.01$
PEEP (cmH_2O), Mean ± SD	8.4 ± 1.1	10.0 ± 0.3	$P < 0.01$
Driving pressure (cmH_2O), Mean ± SD	17.5 ± 2.0	16.3 ± 2.9	$P = 0.15$
FIO_2 (%), Mean ± SD	71 (54–100)	60 (50–84)	$P = 0.036$

C_{dyn}, dynamic lung compliance; V_T, tidal volume; PEEP, positive end-expiratory pressure.

27



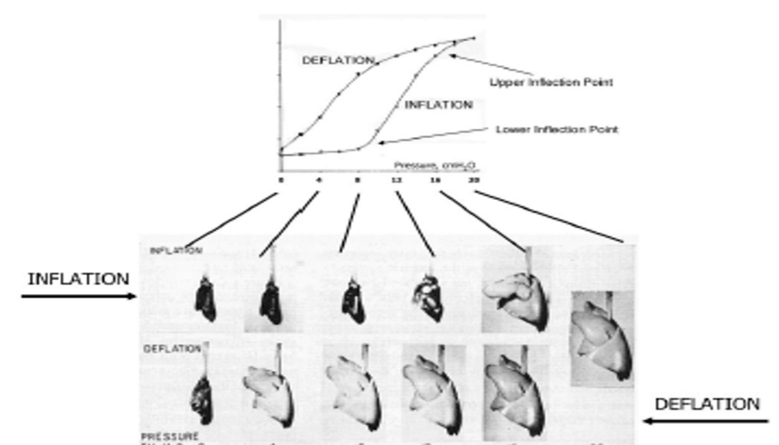


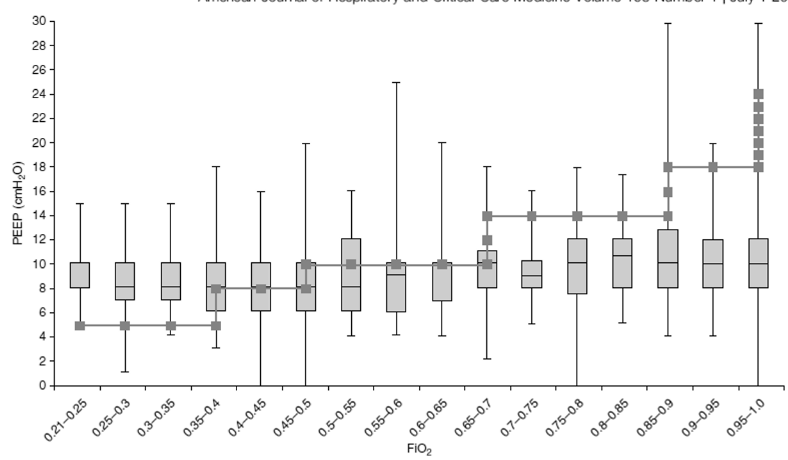
Fig. 5. Upper panel: Pressure-volume curve of an excised cat lung. The bottom panels represent photographs taken at each pressure level during inflation and deflation. Note the marked hysteresis, with much greater inflation and more homogeneous inflation on the deflation limb. Also note that recruitment continues along the inflation limb of the pressure-volume curve as pressure increases above the lower inflection point. (Adapted from Reference 7, with permission.)

28

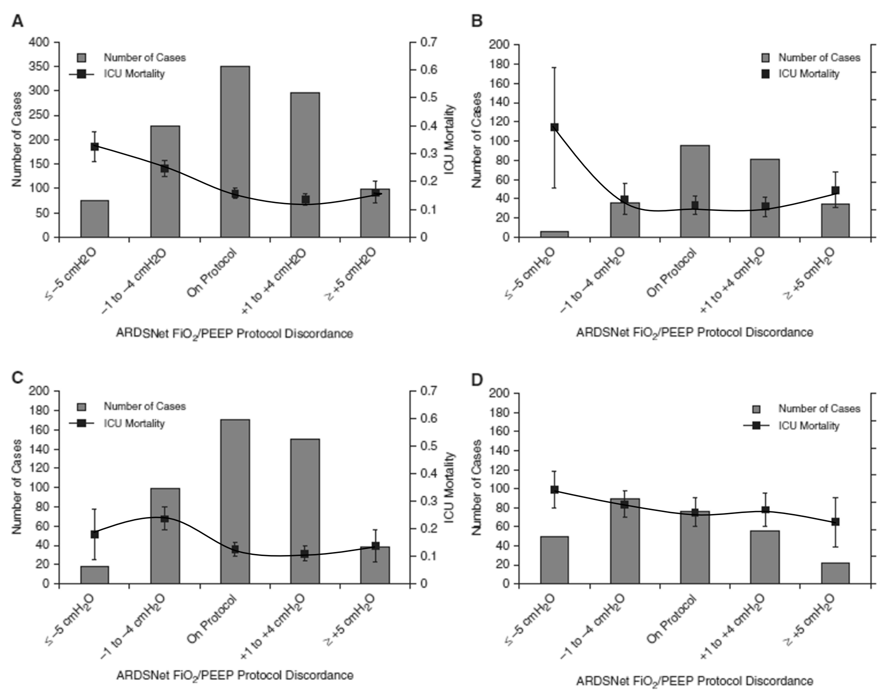
Positive End-Expiratory Pressure Lower Than the ARDS Network Protocol Is Associated with Higher Pediatric Acute Respiratory Distress Syndrome Mortality

Robinder G. Khemani[1,2], Kaushik Parvathaneni[1,3], Nadir Yehya[4], Anoopindar K. Bhalla[1,2], Neal J. Thomas[5], and Christopher J. L. Newth[1,2]

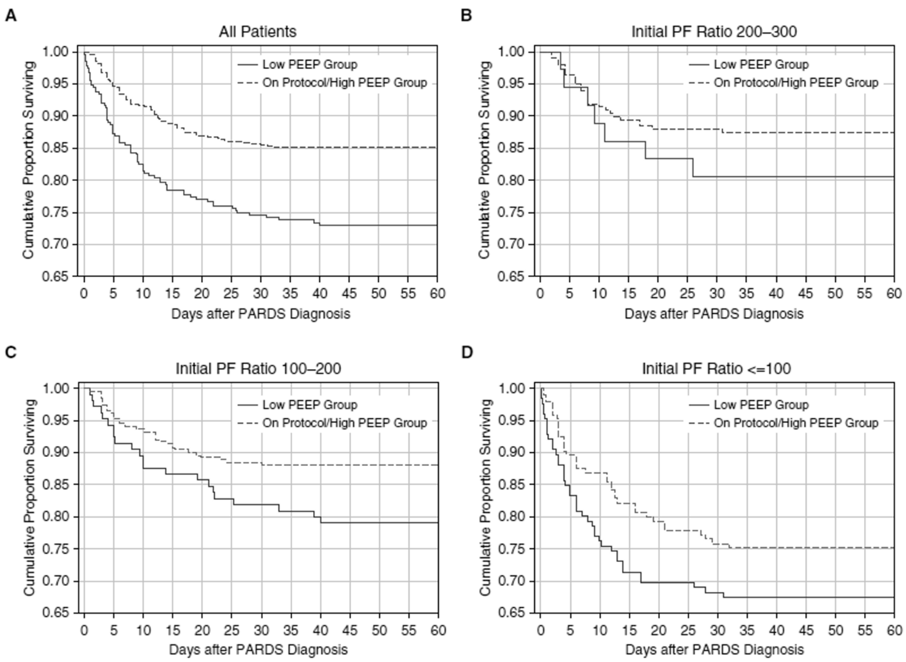
American Journal of Respiratory and Critical Care Medicine Volume 198 Number 1 | July 1 2018



29

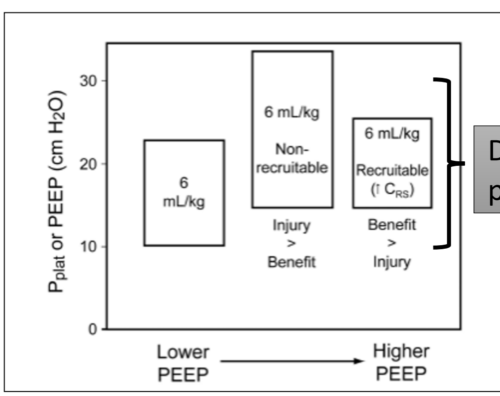


30



31

PEEP ÓPTIMA V/S PEEP ELEVADA



Driving pressure

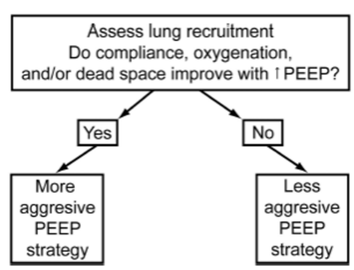


Fig. 2. PEEP titration based on lung recruitability.

CHEIFETZ, RESPIR CARE OCT 2011 VOL 56 N° 10

Δ PIM-PEEP < 10 cmH2O pulmón sano

Intensive Care Med (2017) 43:1764–1780

32

Otras recomendaciones

33

TET

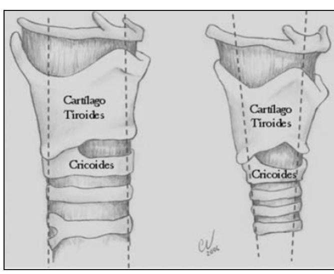


Figura 4. La laringe del adulto tiene forma cilíndrica y la del niño de embudo. En menores de ocho años, esta diferencia permite la intubación con cánulas sin globo por el sello fisiológico que ejerce el cartílago cricoides.

ANESTHESIOLOGY

The Journal of

THE AMERICAN SOCIETY OF ANESTHESIOLOGISTS, INC.

Volume 12 JULY, 1951 Number 4

SOME ANATOMIC CONSIDERATIONS OF THE INFANT LARYNX INFLUENCING ENDOTRACHEAL ANESTHESIA*

JAMES E. ECKENHOFF, M.D.
Philadelphia, Pennsylvania

Received for publication October 10, 1950

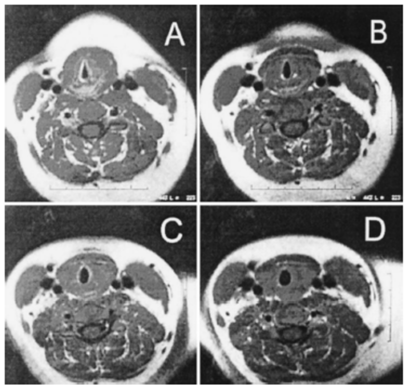
THE endotracheal technic of administering anesthetic agents to infants and children is being employed with increasing frequency. Anesthesiologists trained in pediatric anesthesia are more often than not likely to consider this technic the one of choice for general anesthesia. Leigh and Belton (1) mentioned using the endotracheal route in over 50 per cent of their anesthesias. At the Children's Hospital of Philadelphia the method is used in over 65 per cent of all anesthesias. There the technic is employed most often with the newborn (98 per cent of all infants two weeks of age or less) and somewhat less frequently with

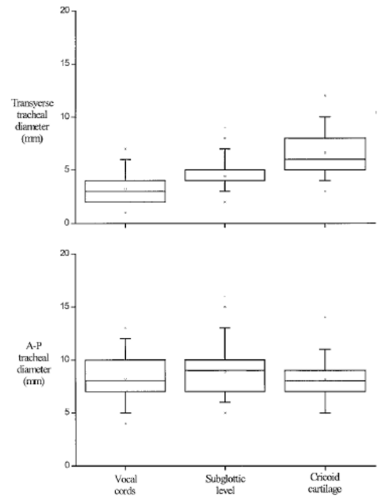
34

Anesthesiology 2003; 98:41–5

Developmental Changes of Laryngeal Dimensions in Unparalyzed, Sedated Children

Ronald S. Litman, D.O.,* Eric E. Weissend, M.D.,† Dean Shibata, M.D.,‡ Per-Lennart Westesson, M.D., Ph.D., D.D.S.§





35

Uso de TET con cuff

Table 6 Stridor rates per age group. NS, not significant

Age groups	Cuffed tubes (final) (*n*)	Stridor (*n*)	Uncuffed tubes (final) (*n*)	Stridor (*n*)
All (A–D)	1197	53 (4.4%)	1049	49 (4.7%)NS
A: 0 to <8 months	326	9 (2.8%)	298	14 (4.7%)NS
B: 8 to <18 months	247	15 (6.1%)	234	8 (3.4%)NS
C: 18 to <36 months	311	15 (4.8%)	266	17 (6.4%)NS
D: 36 to <60 months	313	14 (4.8%)	251	10 (4.0%)NS

20 cmH2O (14,7 mmHg)

1 cmH2O = 1,36 mmHg

Weiss, et al Br J Anaesth 2009; 103:867-873

36

Asincronía Paciente Ventilador

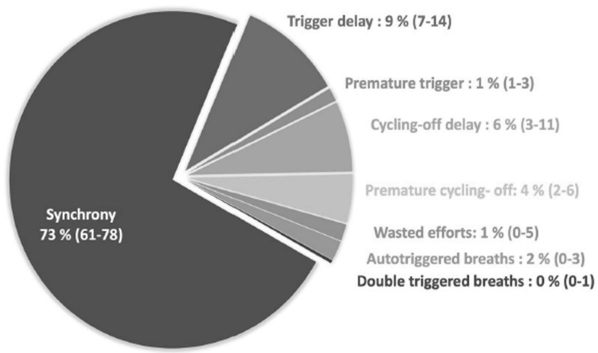


Fig. 2 Contribution of the different types of asynchrony in the total time spent in conflict with the ventilator

Carácterísticas de los pacientes

	% tpo < 39 % asincronía n = 25	% tpo >39 % asincronía n = 9	Valor de p
Edad (m)	14 (2-40)	2 (1-3)	0,007
Tamaño TET	4,0 (3,5-4,5)	3,5 (3,5-3,5)	0,013
TET con cuff	17 (68%)	2 (22%)	0,019
PSV	10 (40 %)	0 (0%)	0,034

Mortamet *et al. Ann. Intensive Care* (2017) 7:122
https://doi.org/10.1186/s13613-017-0344-8

37