Non-invasive Ventilation of the Newborn

From Delivery to Discharge

Case Report

- 24 weeks GA, Abruptio Placentae & premature contractions. Apgar 8/8. Weight 610 g (25%)
- Precipitous delivery → late arrival of pediatrician
- Ram cannula NCPAP/NIPPV from delivery room
- 89 days of non-invasive ventilatory support
- Short period of nasal HFV
- Ductus treated with fluid restriction

Case Report

- Gastro: PN + feeding tube. 12 days: complete enteral nutrition
- Infectious: workup x 2 sterile
- Neurological: Brain ultrasound normal X 3
- ROP I without plus disease
- Discharge: 94 days, weight 2560gr , room air

THE JERUSALEM POST

HEALTH & SCIENCE

By JUDY SIEGEL-ITZKOVICH | 07/29/2014 16:40

Jerusalem baby makes history at Shaare Zedek

Baby girl born at only 24 weeks, needs no ventilation and is going home three months later.

Non Invasive Ventilation

- No intubation. Gas delivered to the lungs through nostrils. “Facilitated Ventilation”

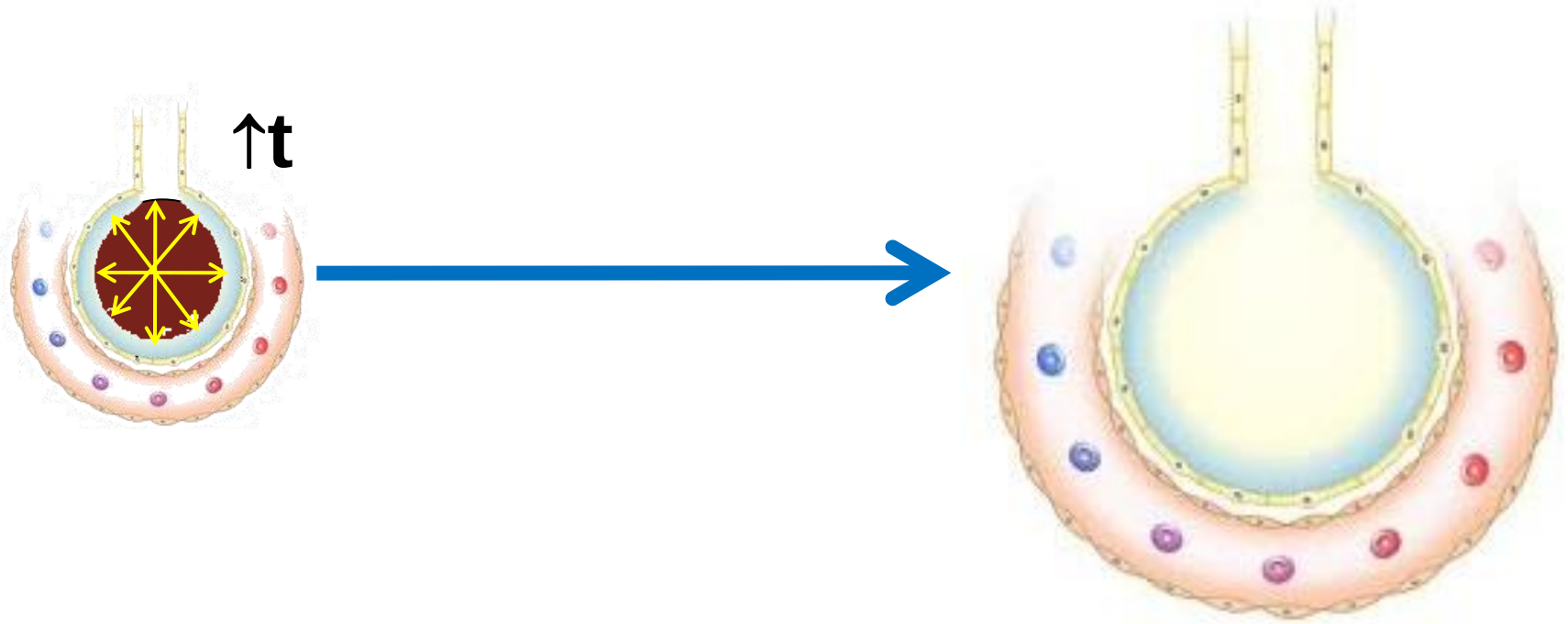
- **P**ressure = **F**low X **R**esistance (constant)

- ↑ P ⇒ ↑ F x R (CPAP)
- ↑ F x R ⇒↑ P (HFNC)

NCPAP

- Closed System (in theory)
- Positive pressure is set $\rightarrow$ Gas flow $\propto$ pressure
- $\uparrow$ FRC $\Rightarrow \uparrow$ oxygenation
- $\uparrow$ alveolar radius at end of expiration$\rightarrow$

How CPAP Helps?



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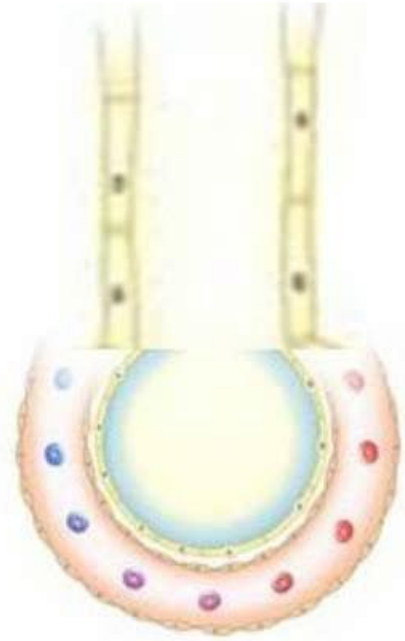

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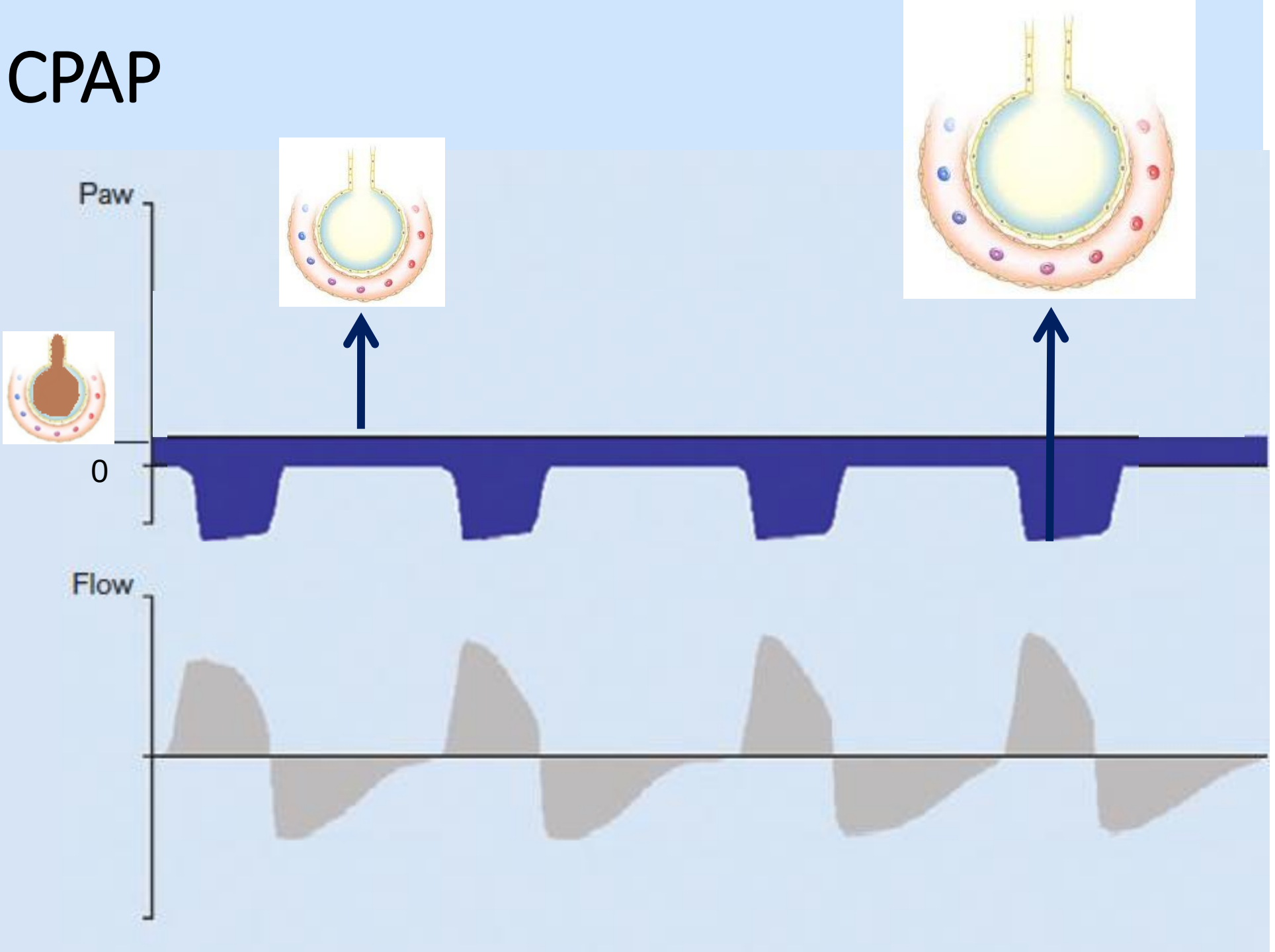
- Alveolar recruitment
- Same interface may also generate nasal IPPV

CPAP



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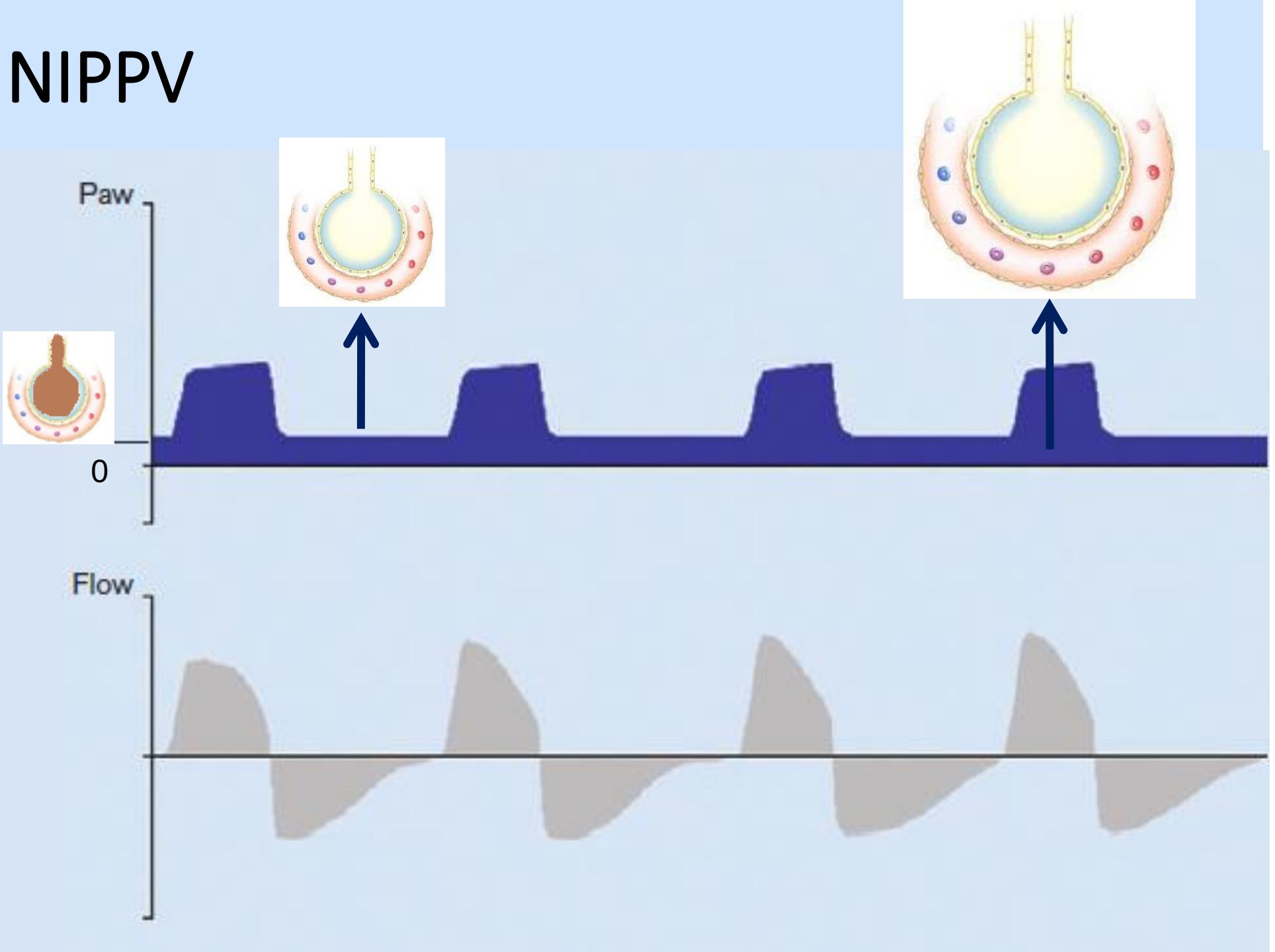
NIPPV



Si-PAP vs. NCPAP: RCT (n=1,009; <1,000 grams BW; GA < 30 weeks)

	Si-PAP (n=504)	NCPAP (n=503)	p
BW, g mean (SD)	802 (131)	805 (127)	NS
GA	26.1 (1.5)	26.2 (1.5)	NS
Re-Intubated post-randomization	59.5 %	61.8 %	NS
Prior Intubation	46.5 %	45.4 %	0.70
Caffeine Rx	82.9 %	82.9 %	NS
Survived with BPD	33.9 %	31 %	0.32
Death or BPD @ 36 wks PMA	38.4 %	36.7 %	0.56

NIPPV= Most Centers used Si-PAP; Suggested Settings: PIP 9-10; Vent: PIP 2-4 above PEEP; Max PIP 18; Rate 10-40; IT 0.3-1 s; No data on Surfactant Rx

Kirpalani H et al. NEJM 369:611-20; August, 2013

Bilevel CPAP vs NIPPV

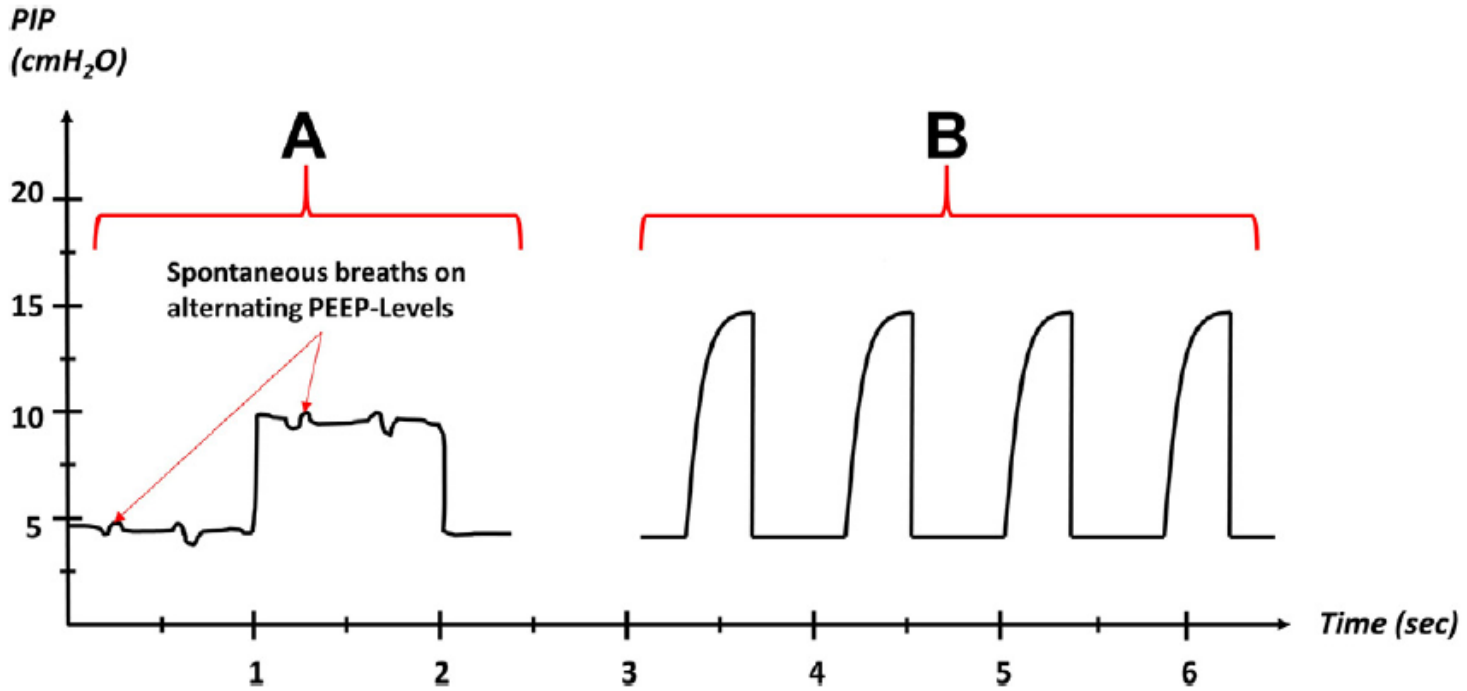
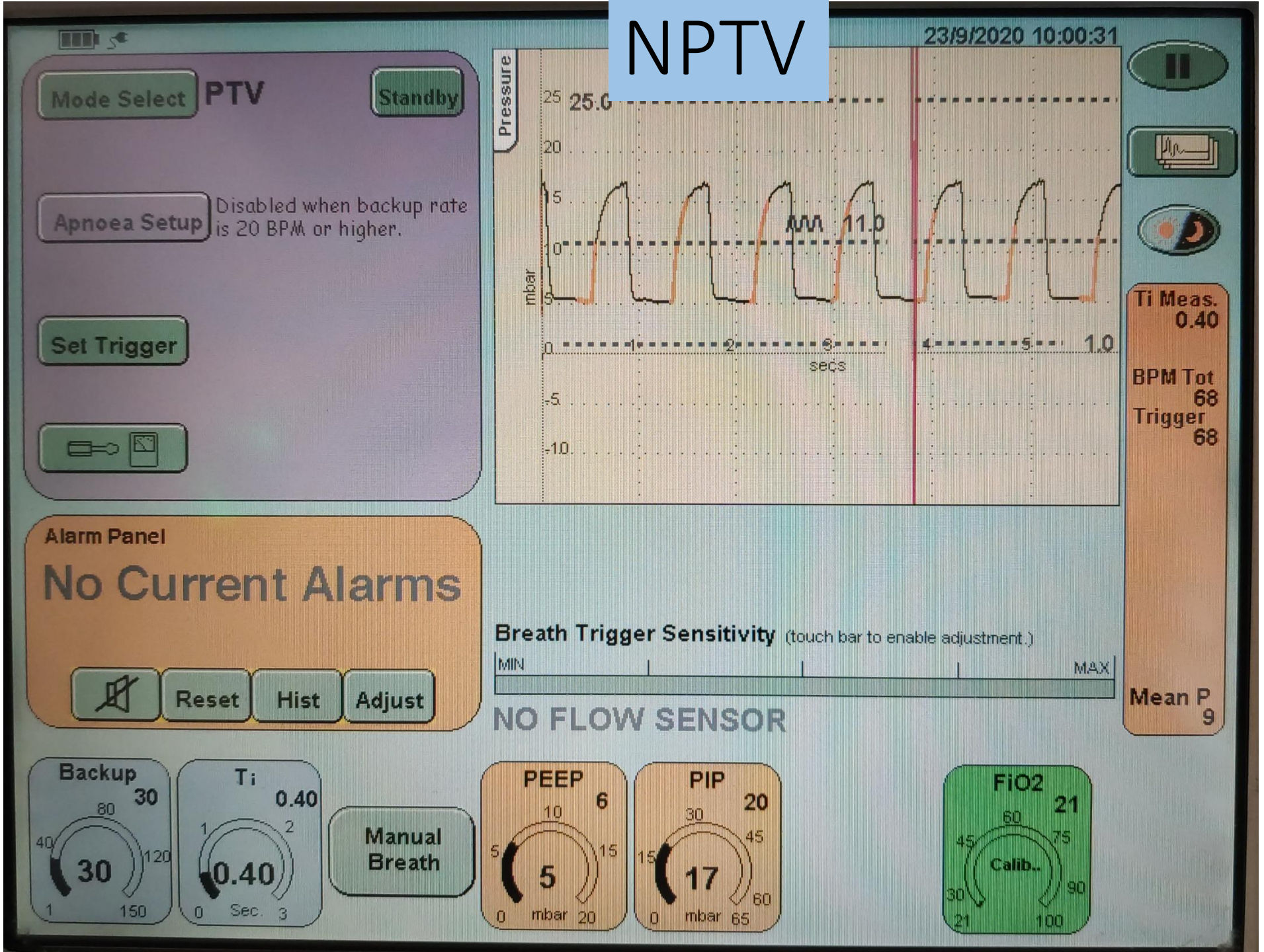


Fig. 1. Differences in pressure wave patterns during (*A*) bilevel nasal intermittent positive pressure ventilation (NIPPV) and (*B*) conventional mechanical ventilator-driven NIPPV. PEEP, positive end-expiratory pressure; PIP, peak inspiratory pressure.

NPTV


23/9/2020 10:00:31
Mode Select
PTV
Standby
Apnoea Setup
Disabled when backup rate is 20 BPM or higher.
Set Trigger
Pressure
25.0
20
5
0
-5
-10
mbar
11.0
1.0
secs
Ti Meas.
0.40
BPM Tot
68
Trigger
68
Alarm Panel
No Current Alarms
Reset
Hist
Adjust
Breath Trigger Sensitivity (touch bar to enable adjustment.)
MIN
MAX
NO FLOW SENSOR
Mean P
9
Backup
30
80
40
120
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Ti
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2
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3
Manual Breath
PEEP
6
10
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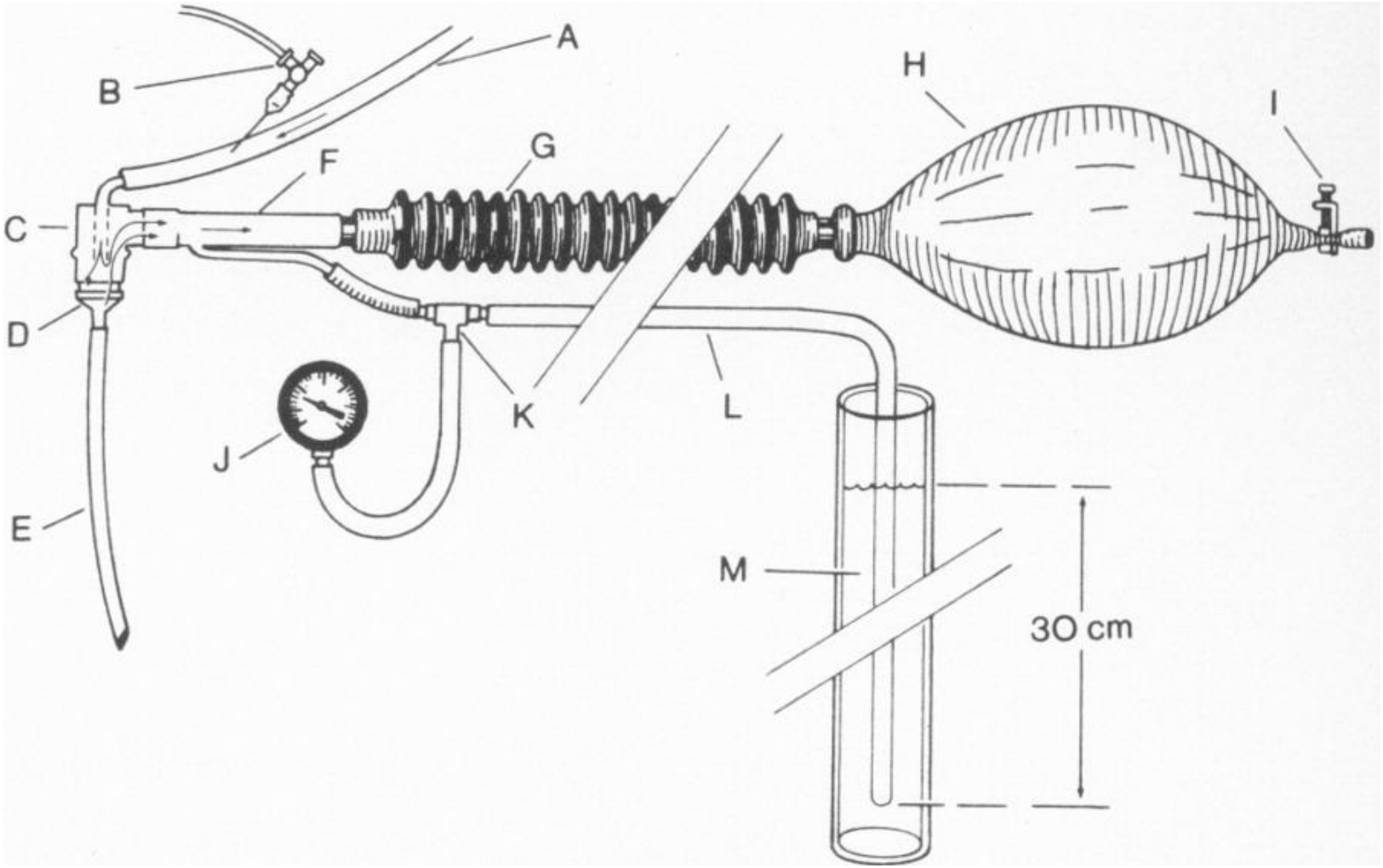
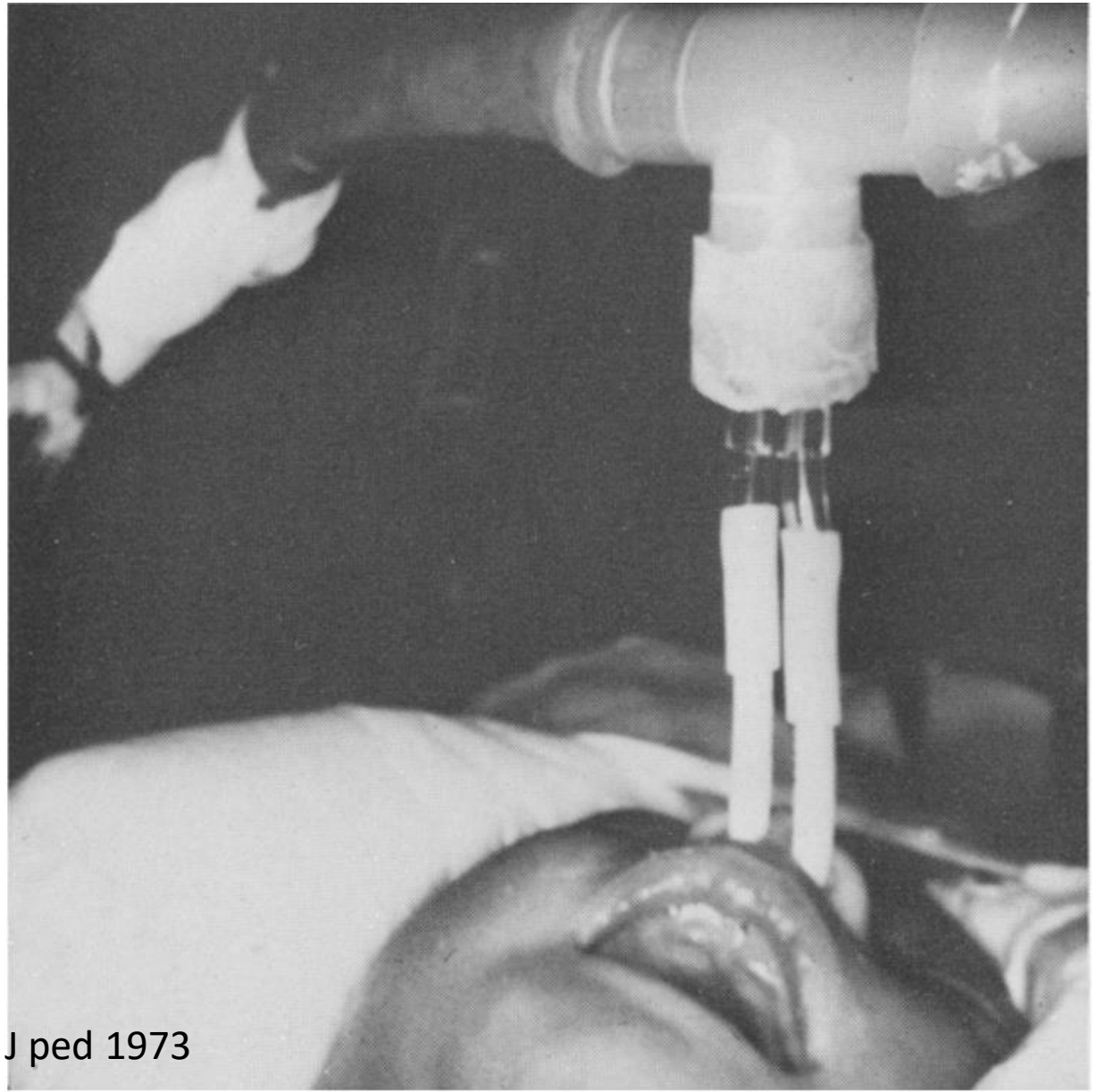


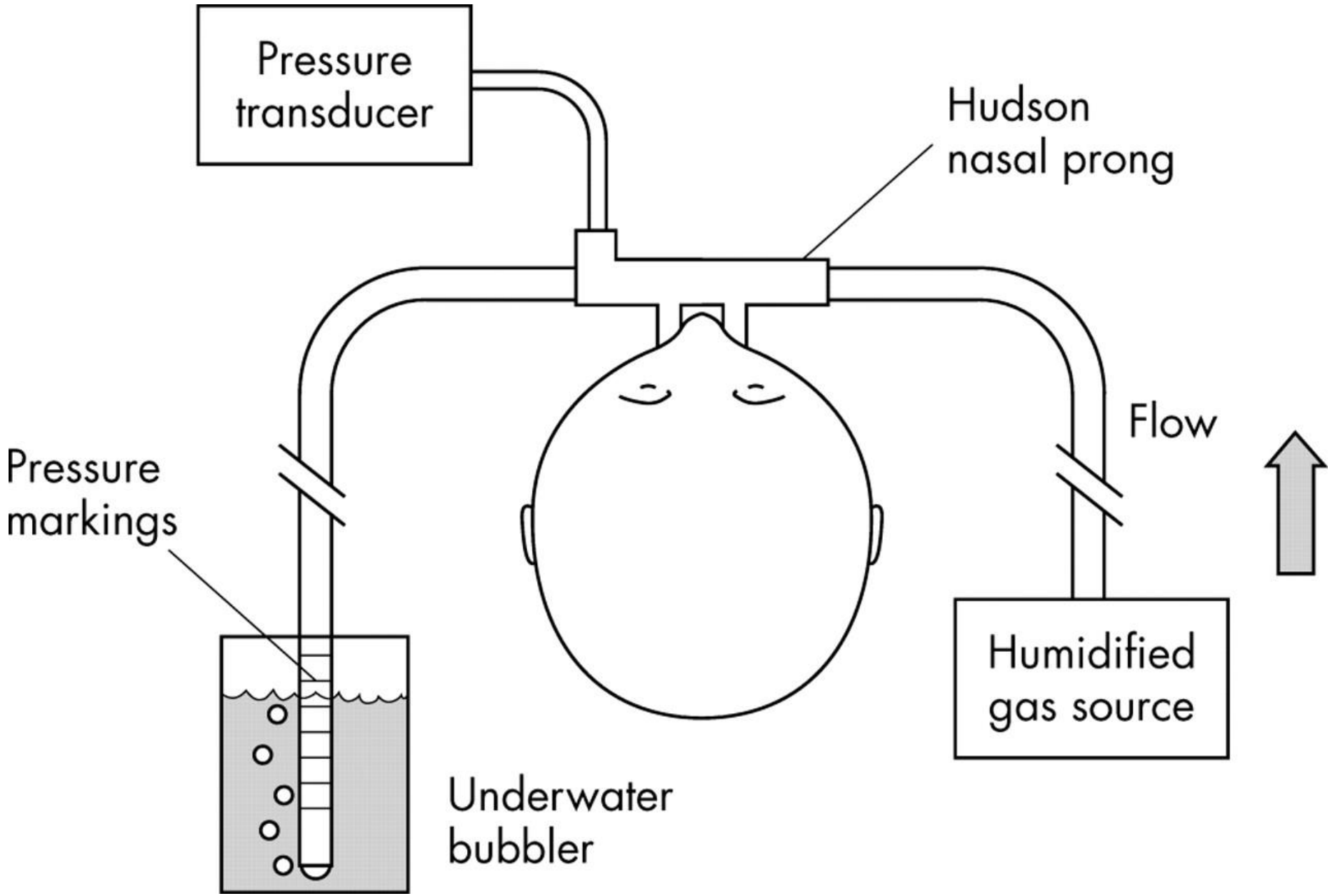
Gregory GA et al. N Engl J Med 1971;284:1333-1340.

1st NCPAP

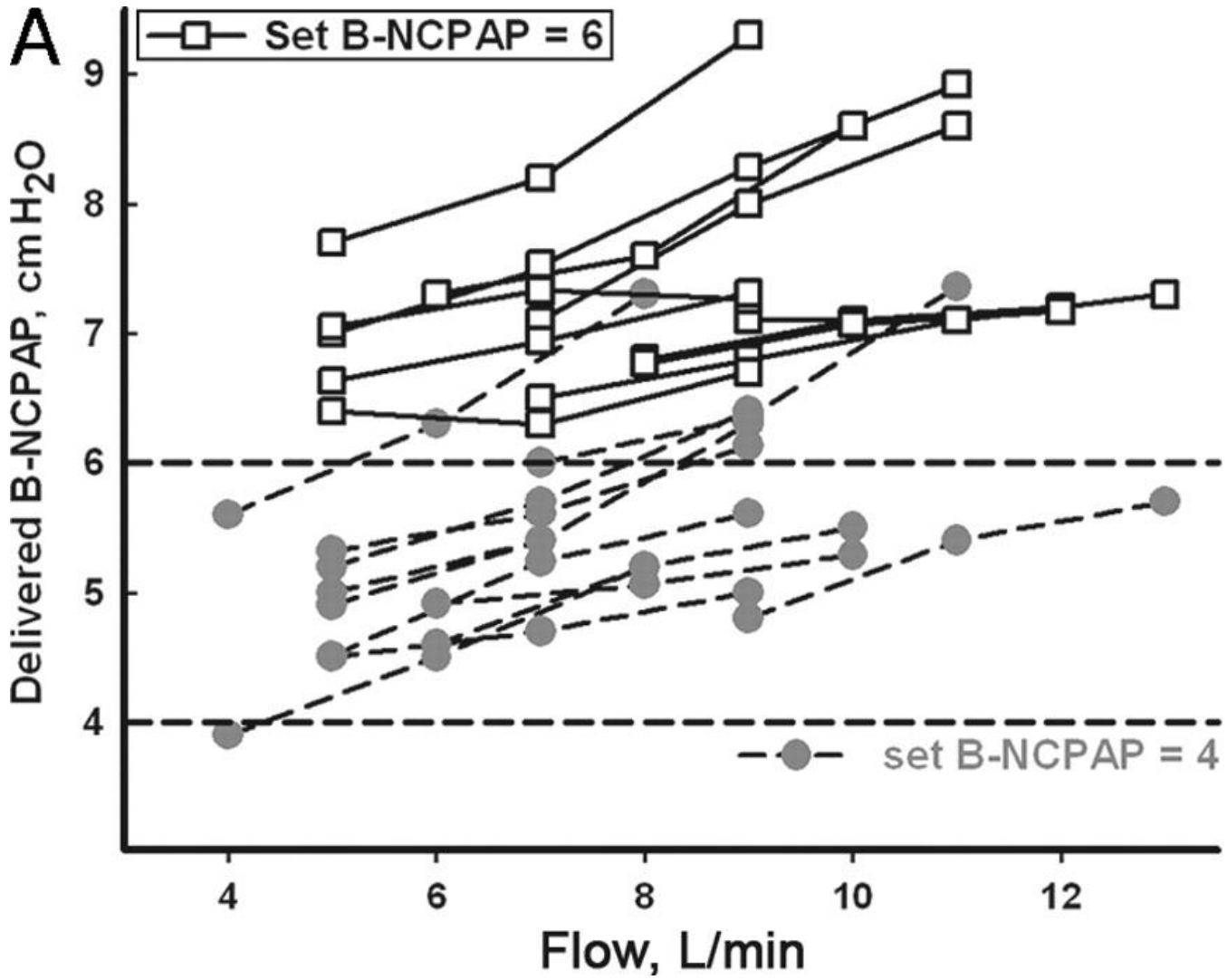


Novogroder et al J ped 1973

NCPAP


Pressure transducer
Hudson nasal prong
Flow
Pressure markings
Humidified gas source
Underwater bubbler

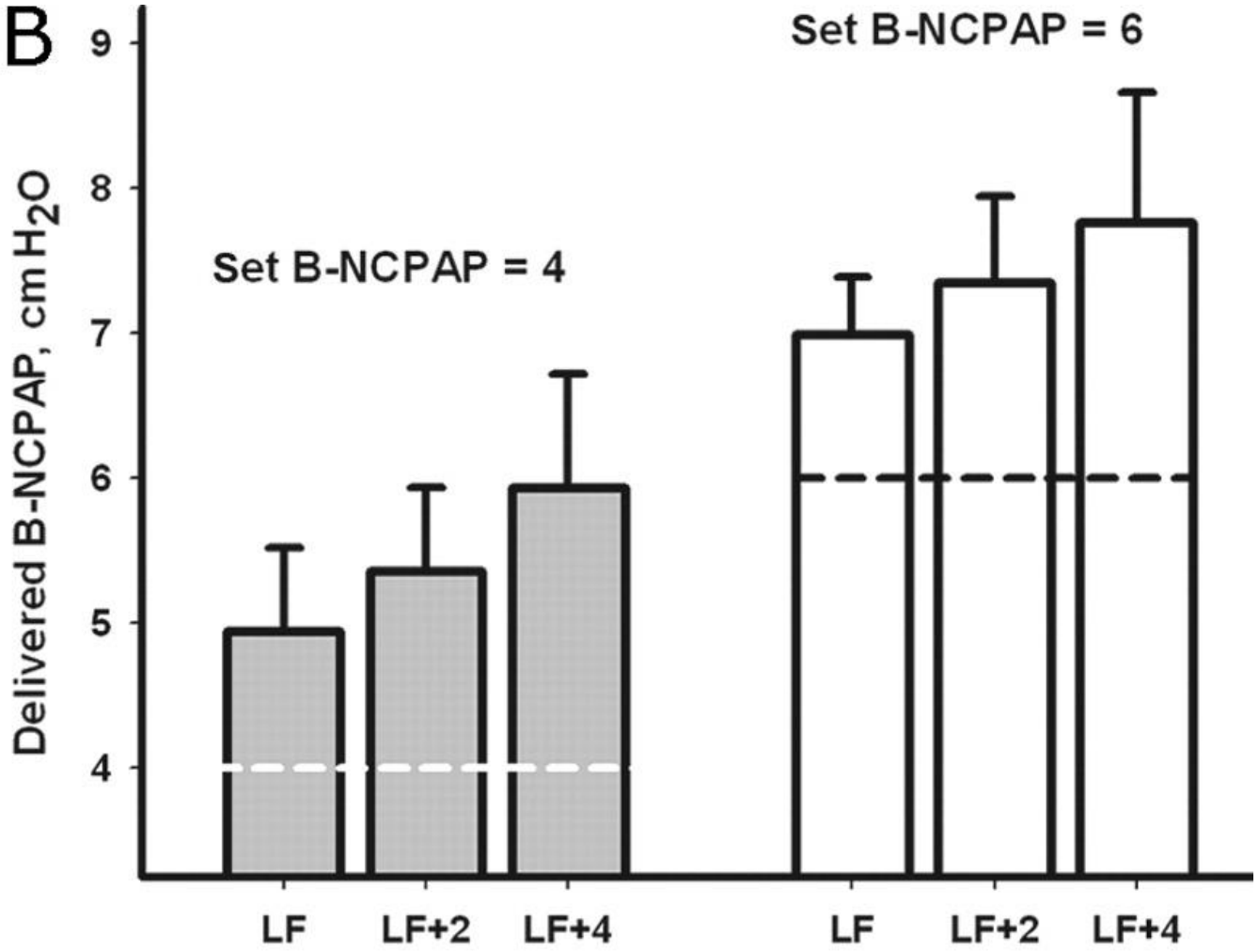
Delivered Pressures at Increasing Flow Rates at 4 and 6 cmH2O B-NCPAP for 19 individual infants



Doron J. Kahn et al. Pediatrics 2008;122:1009-1013

PEDIATRICS®

Delivered Pressures at increasing flow rates at 4 and 6 cmH2O B-NCPAP Averages for All infants



LF indicates lowest flow rate at which bubbling occurred

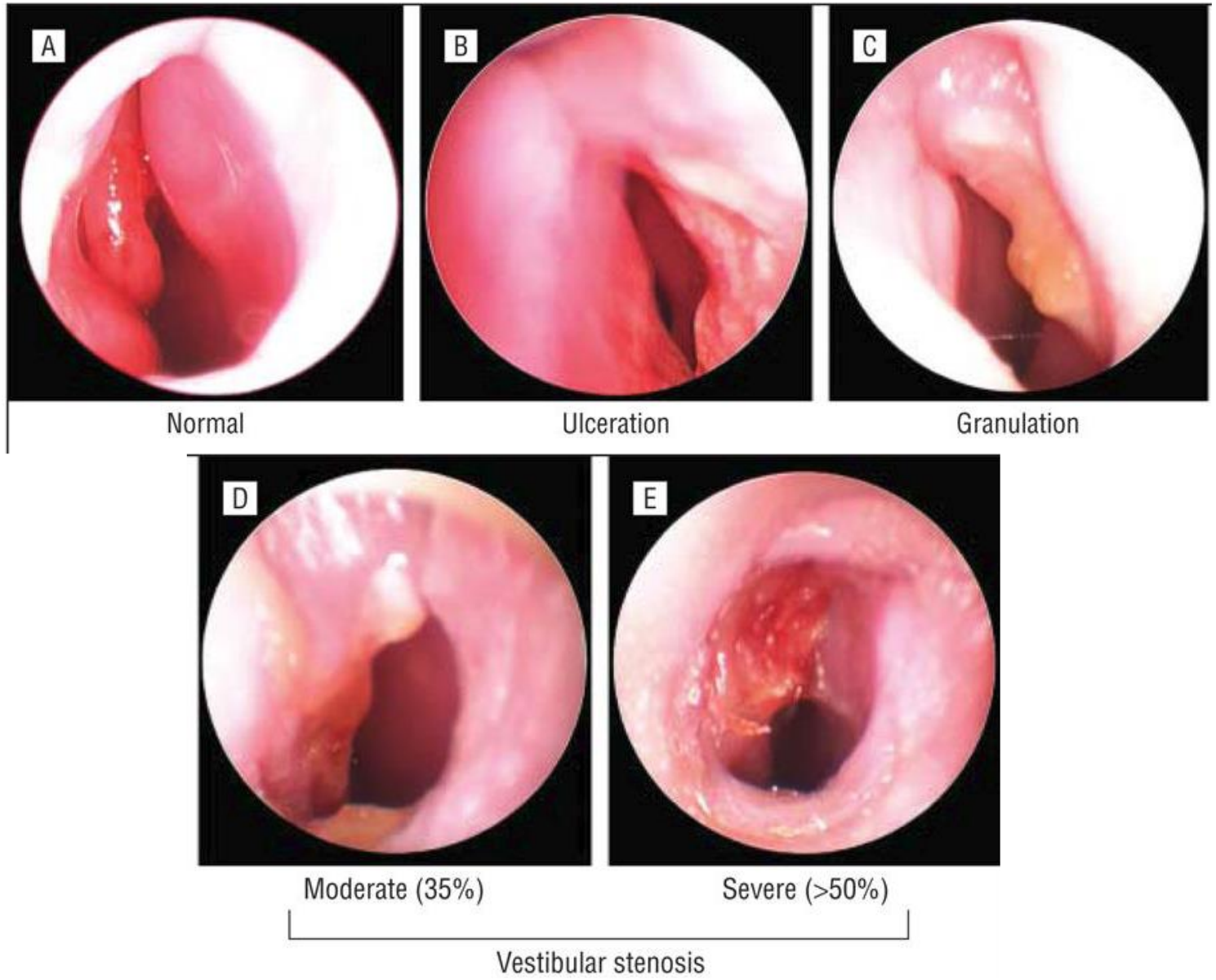
Doron J. Kahn et al. Pediatrics 2008;122:1009-1013

PEDIATRICS®

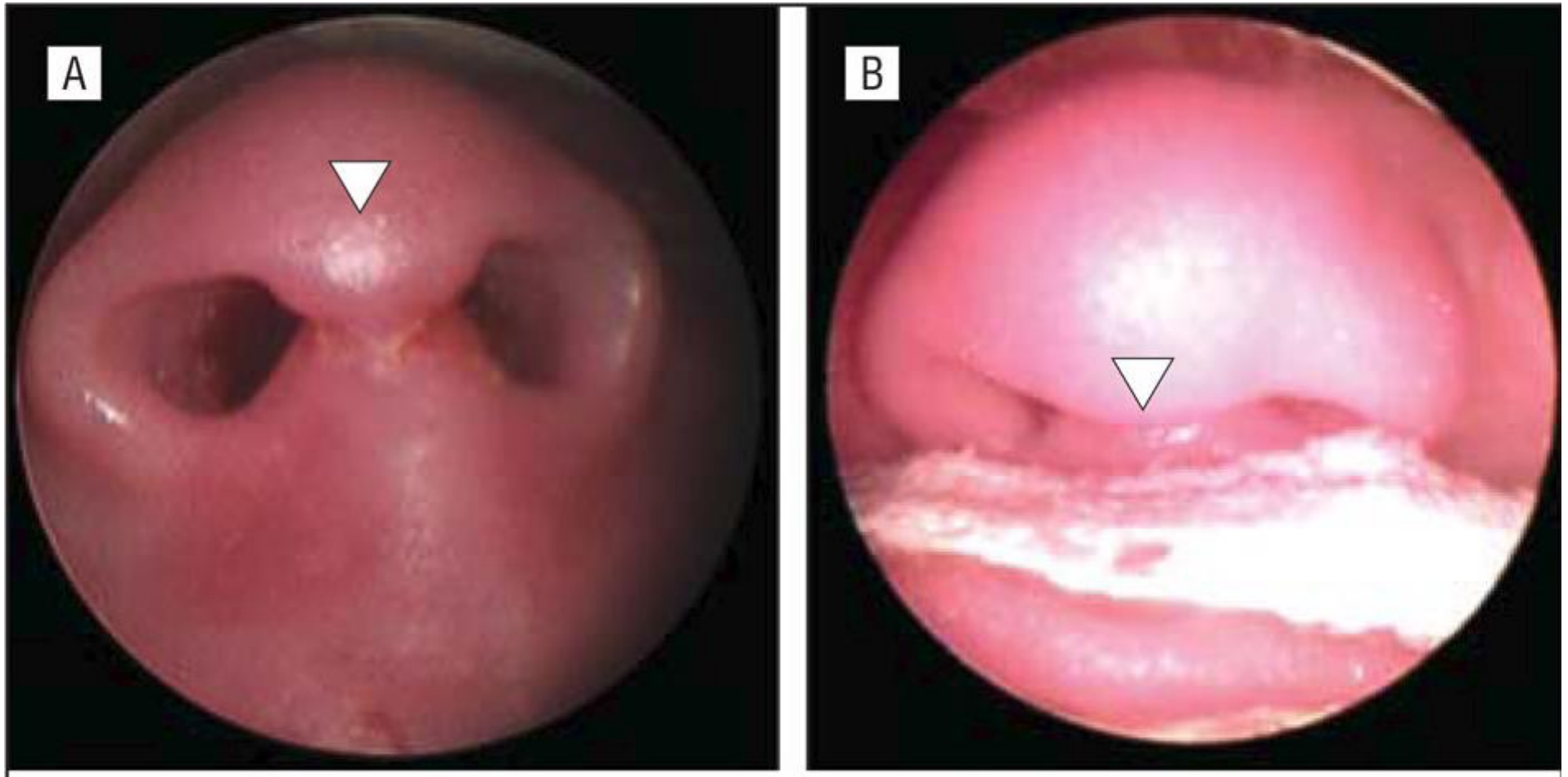
NCPAP


NCPAP

CPAP Nasal Lesions



CPAP Septum Lesions



Early necrosis
(10 d of nasal CPAP use)

Nearly complete necrosis
(12 d of nasal CPAP use)

High Flow Heated Humidified Nasal Cannula (HFNC)

- Flow is set $\Rightarrow$ Pressure depends on airway resistance
- Vapotherm
- Optiflow (F&P)
- “Oxygen therapy” of some ventilators
- Baby friendly interface

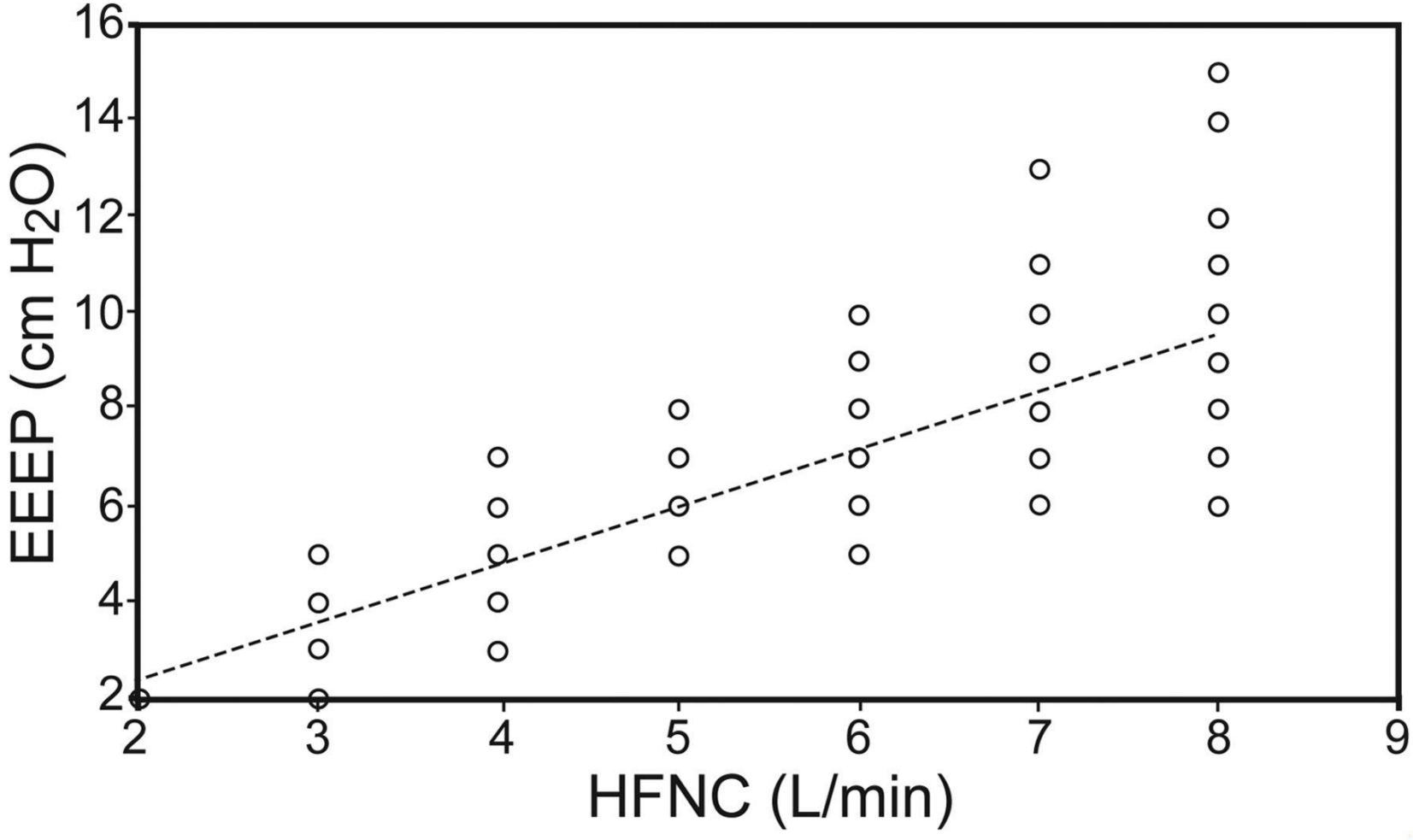
Proposed Mechanisms for Therapeutic Effects of HFNC

- Increased FiO_2 flow
  - ↑ Gas flow prevents entry of room-air
  - Exceeds inspiratory flow → eliminates nasal resistance
  - Washout dead space optimizing minute ventilation

- CPAP Effect
  - Decreases atelectasis and improves V/Q relationship
  - Stimulates respiratory center → ↓ apnea of prematurity
  - Decreases work of breathing

Jeffrey J Ward Respir Care 2013;58:98-122

Association between high-flow nasal cannula (HFNC) and generated end-expiratory esophageal pressures (EEEP) in premature infants.



Narayan P Iyer, and Maroun J Mhanna Respir Care 2016;61:285-290

Proposed Mechanisms for Therapeutic Effects of HFNC

- Greater Comfort
  - Warmed and humidified gas better tolerated, especially with flows 6 L/min
- Humidification of gas restores mucocilliary function
  - Improve secretion mobilization
  - ↓ symptoms of airway hyper-reactivity
- Interface
  - More comfortable
  - Avoids septal injury

Jeffrey J Ward Respir Care 2013;58:98-122

HFNC Compared with Nasal CPAP in Preterm Infants Cochrane 02/2016

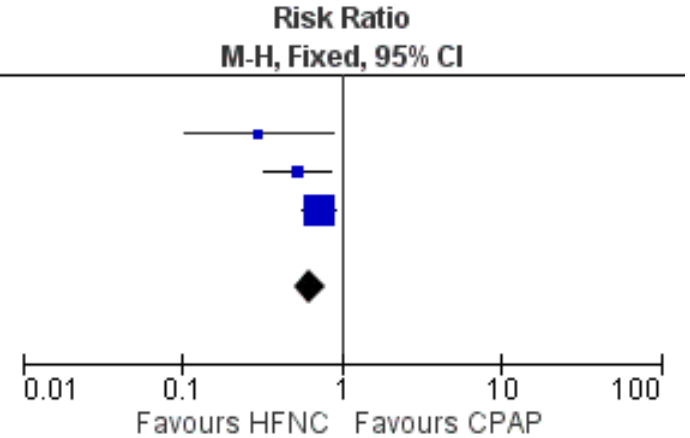
- Similar rates of efficacy for preventing
  - Treatment failure
  - Death
  - CLD
- Less nasal trauma
- ↓ pneumothorax?
- ↓ length of stay

Nasal Trauma

Study or Subgroup	HFNC Events	HFNC Total	CPAP Events	CPAP Total	Weight	Risk Ratio M-H, Fixed, 95% CI
Campbell 2006	0	20	0	20		Not estimable
Yoder 2013	4	102	15	115	11.5%	0.30 [0.10, 0.88]
Mostafa-Gharehbaghi 2014	14	42	27	43	21.7%	0.53 [0.33, 0.86]
Manley 2013	60	152	82	151	66.9%	0.73 [0.57, 0.93]
Total (95% CI)		**316**		**329**	**100.0%**	**0.64 [0.51, 0.79]**
Total events	78		124			

Heterogeneity: $Chi^2 = 3.56$, $df = 2$ ($P = 0.17$); $I^2 = 44\%$

Test for overall effect: $Z = 4.09$ ($P < 0.0001$)



Pneumothorax

Study or Subgroup	HFNC Events	HFNC Total	CPAP Events	CPAP Total	Weight	Risk Ratio M-H, Fixed, 95% CI
Collins 2013	0	67	1	65	12.9%	0.32 [0.01, 7.80]
Liu 2014	1	71	2	79	16.0%	0.56 [0.05, 6.00]
Manley 2013	1	152	4	151	34.0%	0.25 [0.03, 2.20]
Mostafa-Gharehbaghi 2014	1	42	3	43	25.1%	0.34 [0.04, 3.15]
Yoder 2013	0	107	1	119	12.0%	0.37 [0.02, 9.00]
Total (95% CI)		**439**		**457**	**100.0%**	**0.35 [0.11, 1.06]**
Total events	3		11			

Heterogeneity: $Chi^2 = 0.25$, $df = 4$ ($P = 0.99$); $I^2 = 0\%$

Test for overall effect: $Z = 1.86$ ($P = 0.06$)

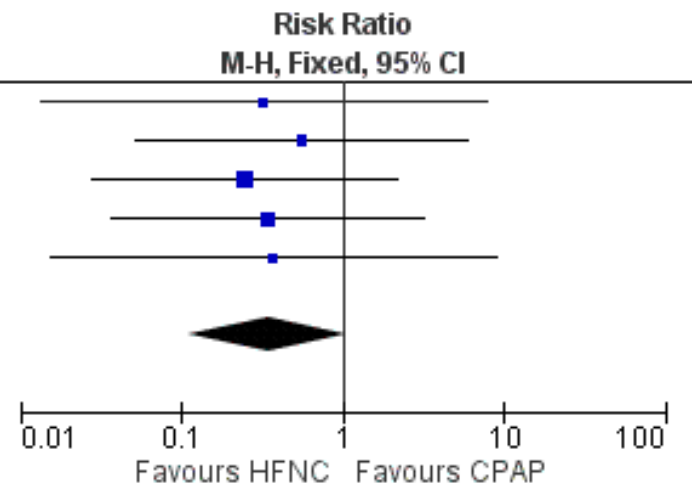


Table 2. Primary Outcome, Intubation within 72 Hours, and Outcomes in the Subgroup and Per-Protocol Analyses.

Outcome	High-Flow Group (N=278)	CPAP Group (N=286)	Risk Difference (95% CI)*	P Value
	no./total no. (%)		*percentage points*	
Primary intention-to-treat analysis				
Treatment failure within 72 hr	71/278 (25.5)	38/286 (13.3)	12.3 (5.8 to 18.7)	<0.001
Gestational age <32 wk	46/140 (32.9)	27/149 (18.1)	14.7 (4.8 to 24.7)	0.004
Gestational age ≥32 wk	25/138 (18.1)	11/137 (8.0)	10.1 (2.2 to 18.0)	0.01
Intubation within 72 hr	43/278 (15.5)	33/286 (11.5)	3.9 (–1.7 to 9.6)	0.17
Gestational age <32 wk	30/140 (21.4)	24/149 (16.1)	5.3 (–3.7 to 14.3)	0.25
Gestational age ≥32 wk	13/138 (9.4)	9/137 (6.6)	2.9 (–3.5 to 9.3)	0.38
Per-protocol analysis				
Treatment failure within 72 hr	64/264 (24.2)	36/279 (12.9)	11.3 (4.8 to 17.8)	<0.001
Intubation within 72 hr	39/264 (14.8)	33/279 (11.8)	2.9 (–2.8 to 8.7)	0.31

* Positive values favor the CPAP group, and negative values favor the high-flow group. Apparent discrepancies in some of the risk differences are due to rounding.

Roberts CT et al. N Engl J Med 2016;375:1142-1151.

From: **Lavizzari A et al. Heated, Humidified High-Flow Nasal Cannula vs Nasal CPAP for Respiratory Distress Syndrome of Prematurity. A Randomized Clinical Noninferiority Trial** JAMA Pediatr. 2016

Table 2. Primary Outcome Results

Outcome	HHHFNC (n = 158)	nCPAP/BiPAP (n = 158)	95% CI of Risk Difference or Difference in Medians	*P* Value[a]
Mechanical ventilation within 72 h, No. (%)	17 (10.8)	15 (9.5)	−6.0 to 8.6	.71
Gestational age[b]				
29^{+0} to 32^{+6}	10 (14.1)	8 (10.9)		.70
33^{+0} to 34^{+6}	2 (3.8)	4 (7.5)		.67
35^{+0} to 36^{+6}	5 (14.7)	3 (9.4)		.76
Age at start of mechanical ventilation, median (IQR), h	27.0 (8.0-36.0)	7.0 (3.0-19.0)	−24.5 to 0.0	.06
Duration of mechanical ventilation, median (IQR), d	3.2 (1.2 to 5.0)	3.0 (1.2 to 6.0)	−1.25 to 2.25	.72

Primary Outcome Results

Results

Secon

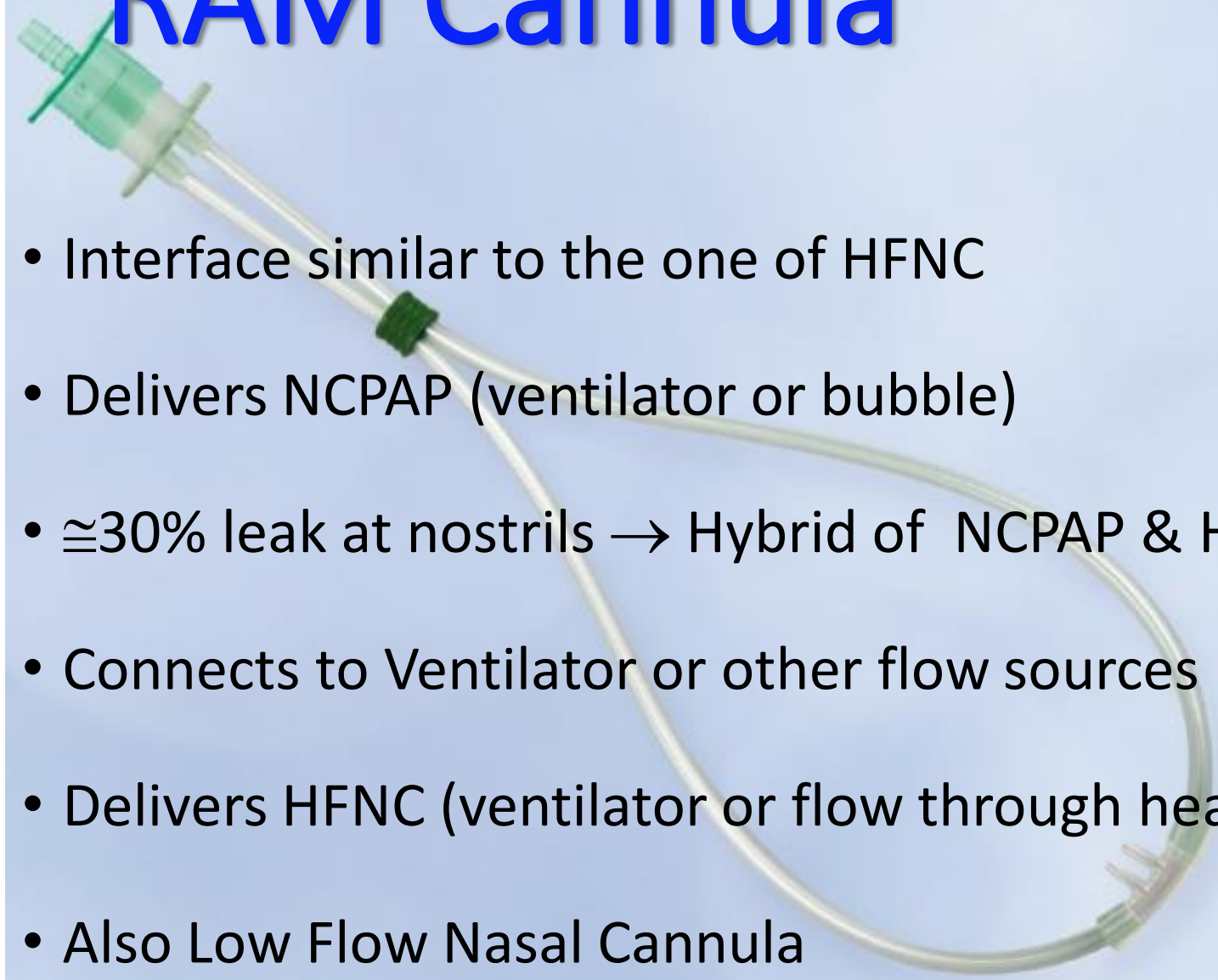
Outcome	HHHFNC (n = 158)	nCPAP/BiPAP (n = 158)	95% CI of Difference in Medians or Risk Difference	*P* Value[a]
Duration received, median (IQR), d				
Respiratory support	4.0 (2.0 to 6.0)	4.0 (2.0 to 7.0)	−1.0 to 0.5	.45
Noninvasive respiratory support	3.5 (2.0 to 6.0)	3.5 (2.0 to 7.0)	−1.0 to 0.5	.48
Oxygen supplementation	0.0 (0.0 to 1.0)	0.0 (0.0 to 0.8)	0.0 to 0.0	.43
Caffeine treatment	12.0 (6.0 to 22.0)	15.0 (7.0 to 24.0)	−1.0 to 4.0	.25
Surfactant, No. (%)				
Administration	70 (44.3)	73 (46.2)	−9.8 to 13.5	.73
Multiple doses	7 (4.4)	8 (5.1)	−4.6 to 6.0	.85
Adverse event, No. (%)				
Air leaks	3 (1.9)	4 (2.5)	−3.3 to 4.5	.70
BPD	7 (4.4)	8 (5.1)	−3.9 to 7.2	.79
Confirmed sepsis	10 (6.3)	13 (8.2)	−4.4 to 8.2	.51
Confirmed NEC	1 (0.6)	2 (1.3)	−2.1 to 3.5	.56
IVH	6 (3.8)	4 (2.5)	−3.2 to 5.8	.52
PDA	8 (5.1)	9 (5.7)	−5.0 to 6.2	.80
ROP	1 (0.6)	0	−1.2 to 2.4	.32
Death	0	1 (0.6)	−1.2 to 2.4	.32
Any[b]	28 (17.7)	28 (17.7)	−9.0 to 9.0	>.99
Full enteral feeding, median (IQR), d	9.0 (6.0 to 15.0)	10.0 (6.0 to 16.0)	−1.0 to 1.0	.53
Exclusive breastfeeding at discharge, No. (%)	49 (31.0)	43 (27.2)	−6.3 to 12.8	.46
Hospitalization, median (IQR), d	20.0 (11.0 to 35.0)	23.0 (12.0 to 36.0)	−4.0 to 2.0	.41
Weight at discharge, median (IQR), g	2250 (2030 to 2485)	2287 (2065 to 2535)	−100.0 to 50.0	.47

Abbreviations: BiPAP, bilevel nasal continuous positive airway pressure; BPD, bronchopulmonary dysplasia; HHHFNC, heated, humidified high-flow nasal cannula; IQR, interquartile range; IVH, intraventricular hemorrhage; nCPAP, noninferior to CPAP; NEC, necrotizing enterocolitis; PDA, patent ductus arteriosus; ROP, retinopathy of prematurity.

[a] Dichotomous outcomes were compared by χ^2 test; continuous outcomes were compared by Wilcoxon 2-sample test.

[b] Includes confirmed sepsis, confirmed NEC, IVH, PDA, ROP, BPD, air leaks, and death.

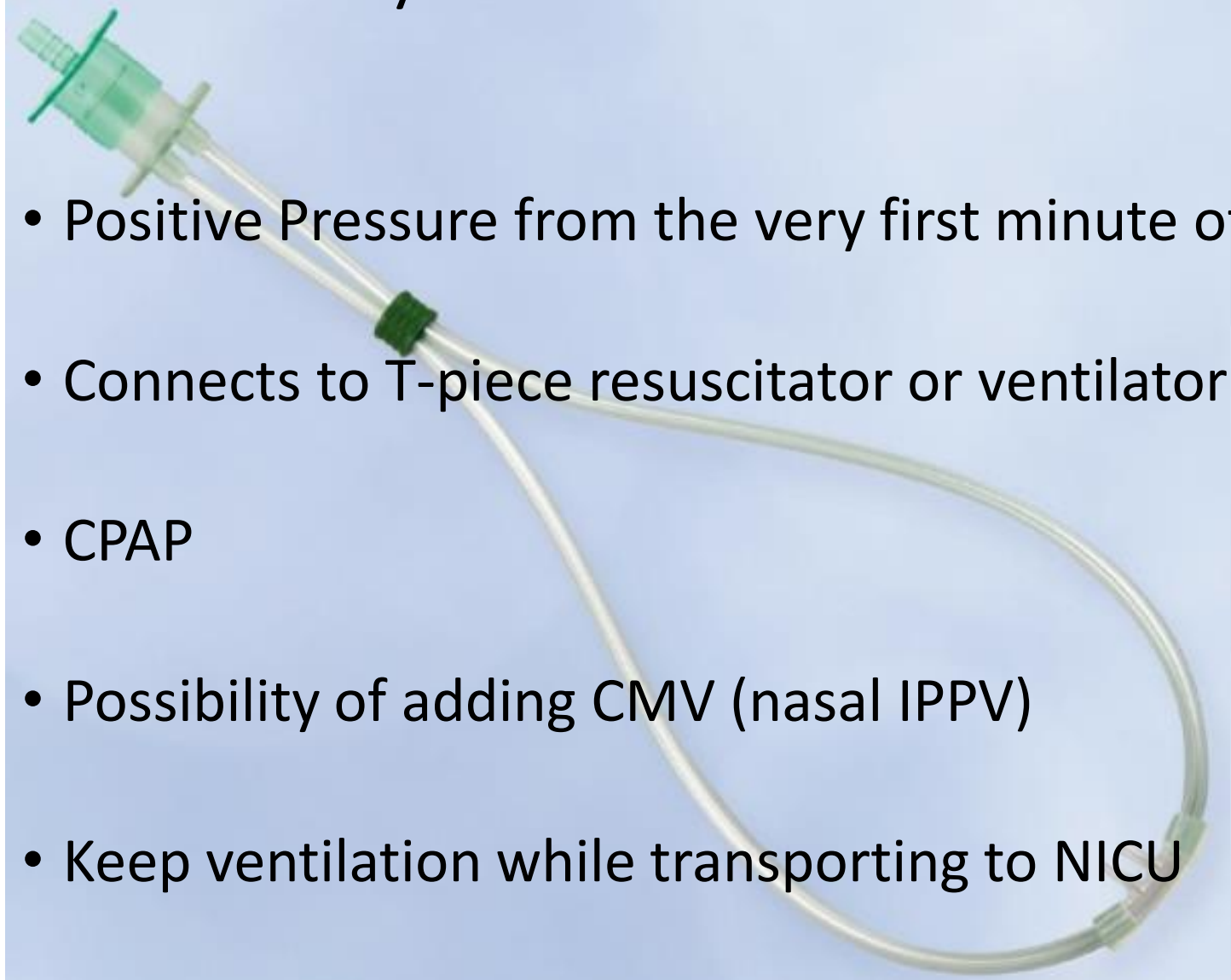
RAM Cannula



- Interface similar to the one of HFNC
- Delivers NCPAP (ventilator or bubble)
- ≅30% leak at nostrils → Hybrid of NCPAP & HFNC
- Connects to Ventilator or other flow sources
- Delivers HFNC (ventilator or flow through heater)
- Also Low Flow Nasal Cannula

Uses

Delivery Room

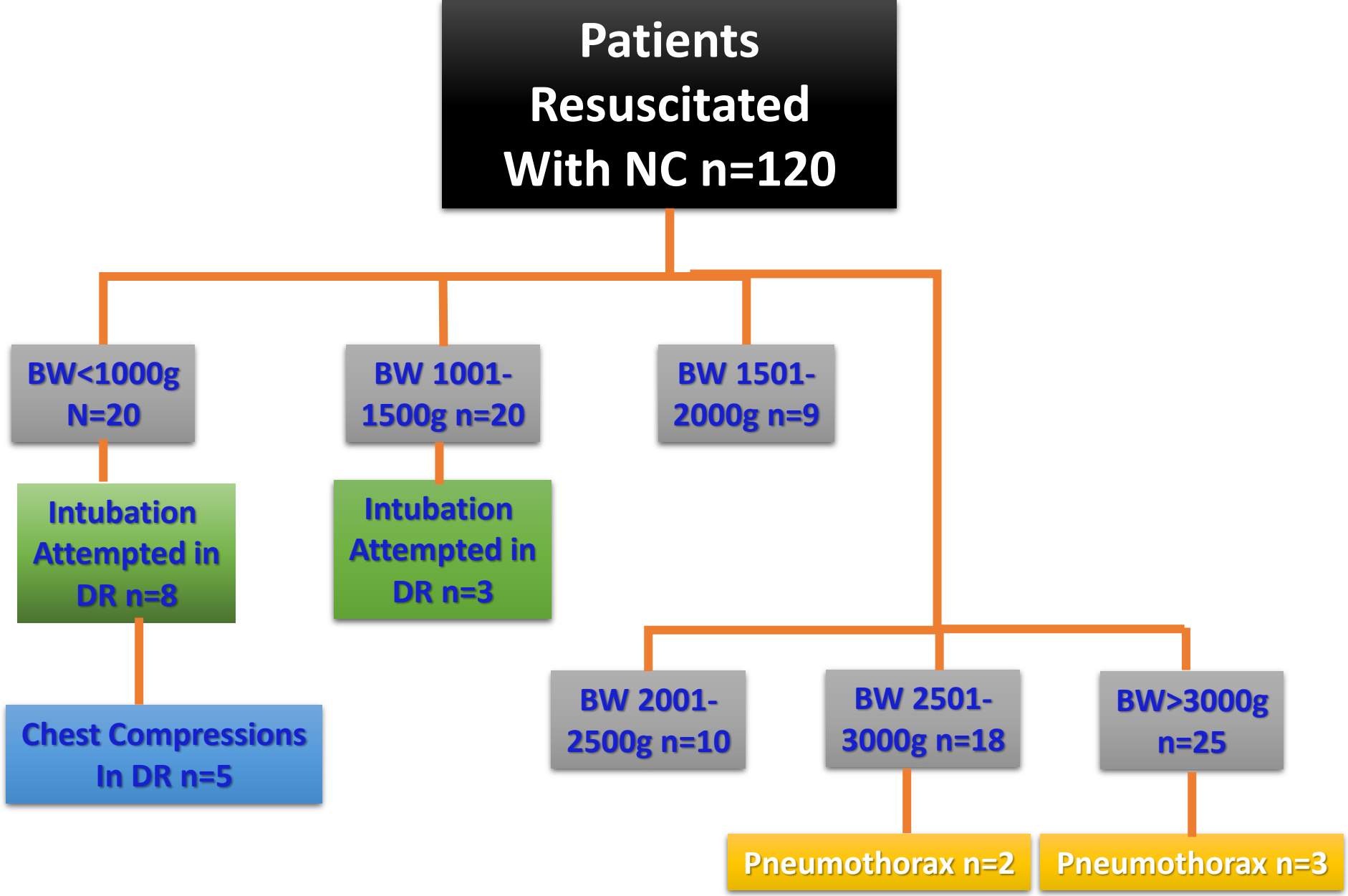


- Positive Pressure from the very first minute of life
- Connects to T-piece resuscitator or ventilator
- CPAP
- Possibility of adding CMV (nasal IPPV)
- Keep ventilation while transporting to NICU

Neonatal Resuscitation in DR Using a Nasal Cannula: A Single-Center Experience

- If respiratory distress, apnea, hypopnea, or a heart rate < 100 → NCPAP of 5 mbar through nasal cannula @ Flow rate of 10 L/min
- If still apnea or bradycardia after 30 seconds of adequate NCPAP→PPV (PIP 20 mbar, 40 to 60 BPM)
- PIP ↑ up to 30 mbar if poor response

Pedro Paz, MD, Rangasamy Ramanathan, Am J Perinat 2014



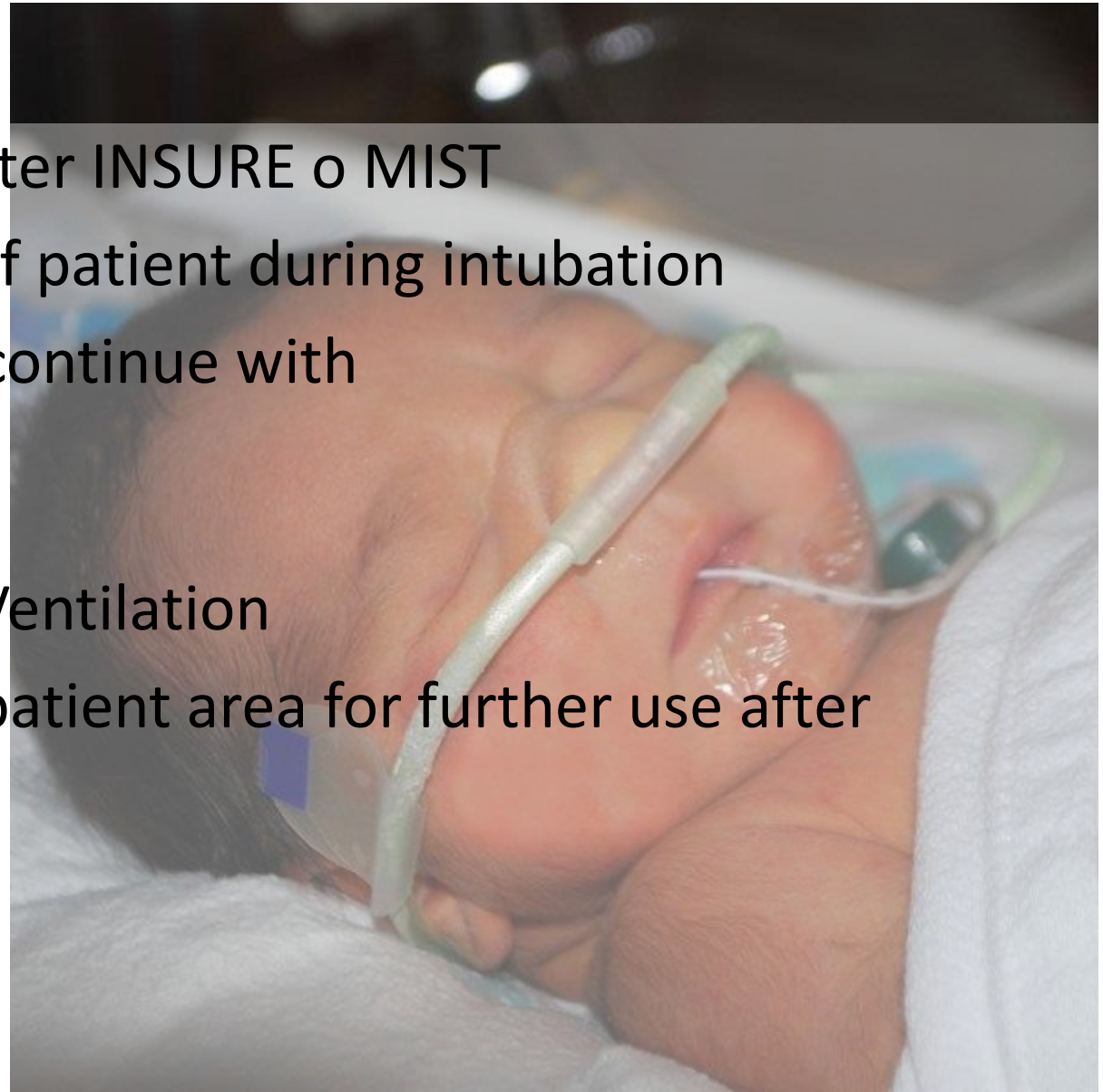
- Effective DR resuscitation with Ram cannula is feasible


54
161

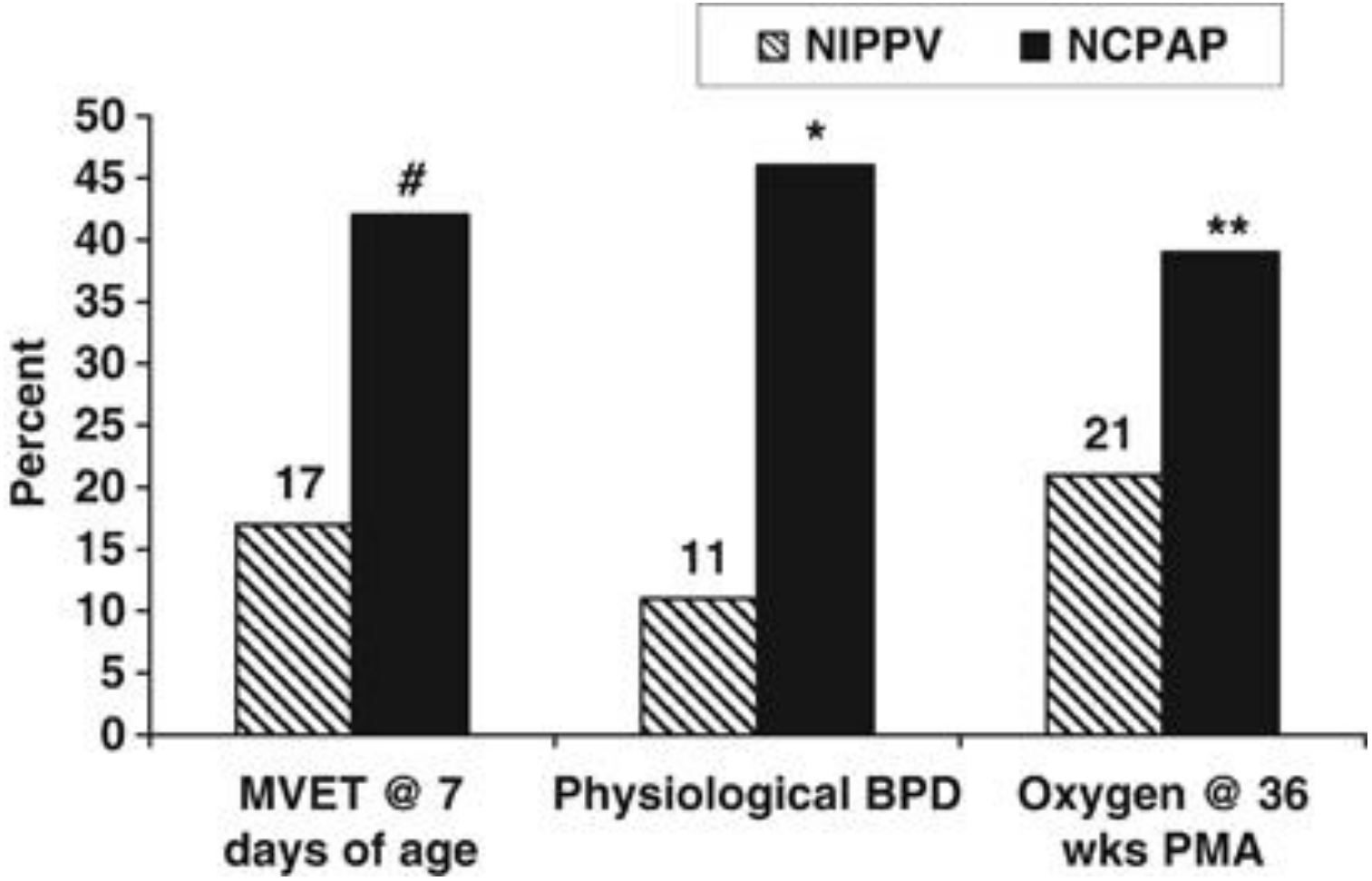

evenaxis

Non Invasive Ventilation in the NICU

- Before, during and after INSURE o MIST
- Allows oxygenation of patient during intubation
- Using the respirator continue with
  - NCPAP
  - NIPPV
- If failure → Invasive Ventilation
- Keep cannula in the patient area for further use after extubation



Nasal IPPV vs CPAP after surfactant for RDS in preterm infants <30 weeks' gestation: a RCT



#*P*=0.005, **P*=0.001, ***P*=0.04, MVET, mechanical ventilation via endotracheal tube

Ramanathan R et al. J Perinatol 2012

Accessory During Invasive Ventilation

- Accidental Extubation
  - Rapid connection to Ram cannula
  - Reanimation prior to re-intubation
  - Trial for continuing with non invasive ventilation

- Programmed Extubation
  - Non-invasive ventilation with Ram cannula
  - Direct connection to the ventilator's whye piece
  - If failure, re-intubate using same ventilator device

Non-Invasive Ventilation Continuation

- Weaning: gradual reduction of pressure and FiO_2

- Low-Flow Oxygen therapy (direct connection to gas blender)

Kangaroo Care

Other Uses

- Bubble CPAP
- High Frequency Nasal Ventilation
- High flow nasal cannula
- Non-Invasive NO administration

Nasal HFOV with Binasal Cannula Appears Effective and Feasible in ELBW Newborns

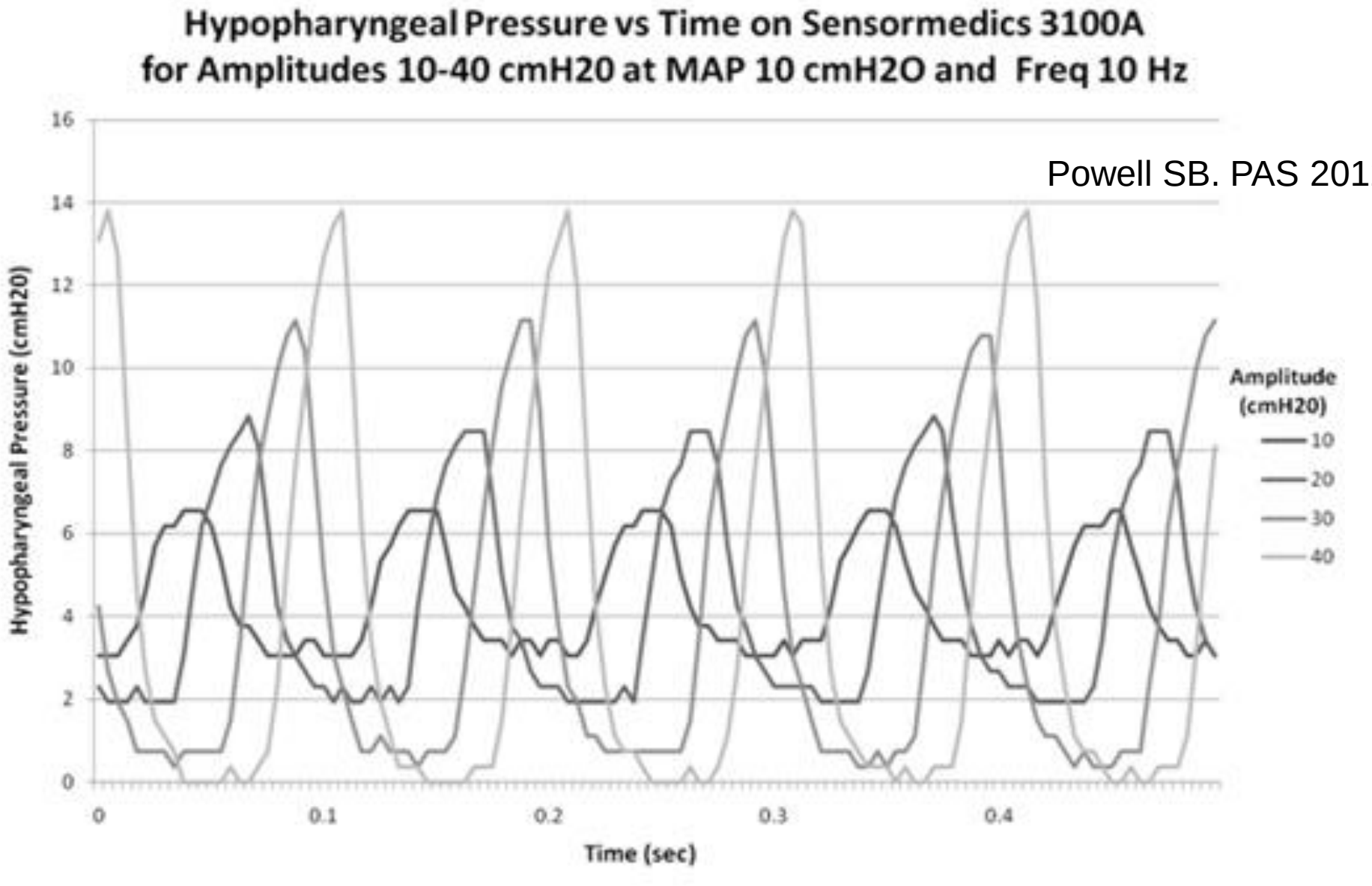
- n-HFOV seems effective and feasible

- 3 premature on n-HFOV through RAM Cannula
  - In two cases, n-HFOV to prevent extubation failure
  - In one case, we used it to avoid intubation

- n-HFOV may be useful in:
  - Early times of respiratory failure
  - Extubation particularly after prolonged intubation

J Trop Pediatr. 2015 Aktas S

Evaluation of High Frequency Ventilation using RAM Nasal Cannula in a Hypopharyngeal Model



Powell SB. PAS 2012

Evaluation of a Nasal Cannula in Noninvasive Ventilation Using a Lung Simulator

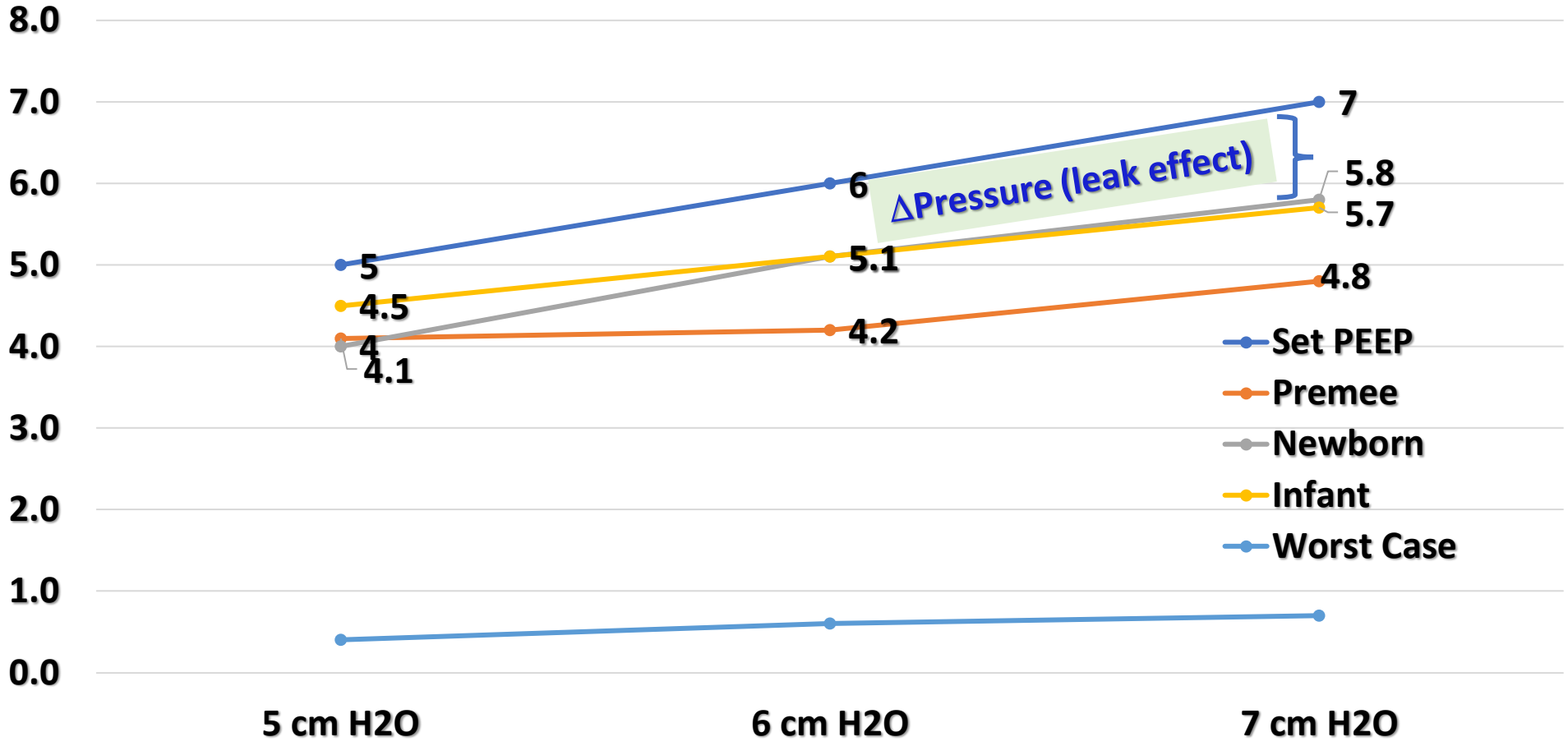
- Lung simulator (IngMar ASL 5000) passive mode
- Simulate a 1–3 kg neonate, normal-moderately sick lungs
- 3 Different PIPs & PEEP were evaluated
- Three sizes of RAM cannula
- Nose designed to keep 30% leak
- Worst case leak (58% leak) largest nostril + smallest cannula

Iyer et al. Respir Care 2015

RAM Cannula vs. Nostril

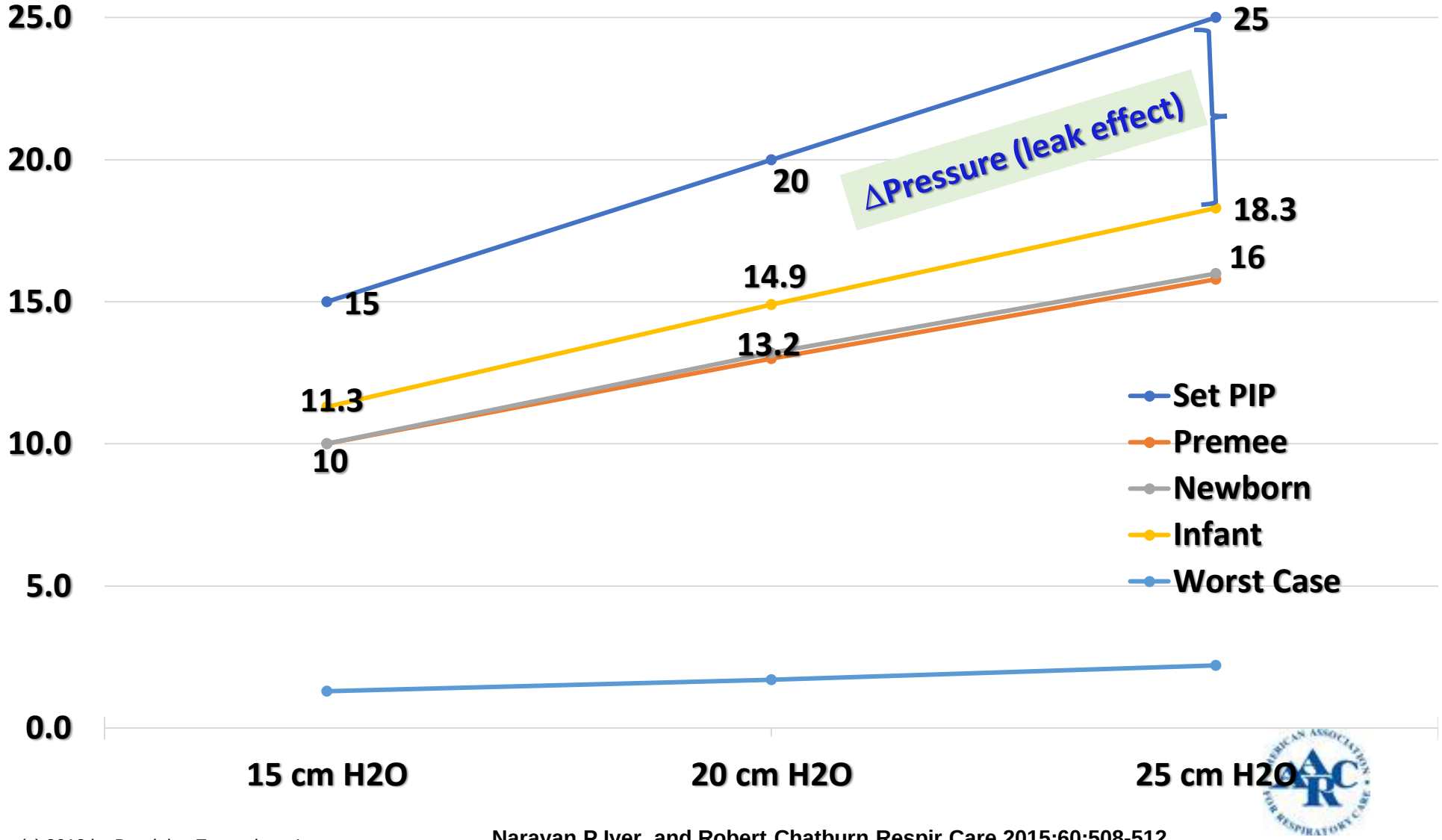
Size	Cannula	Nostril	Leak
Premee	3mm	3.4mm	30%
Newborn	3.5mm	4mm	30%
Infant	4mm	4.6mm	30%
Worst Case	3mm	4.6mm	56%

Measured Peep in a Simulate Nose at Different Set PEEPs



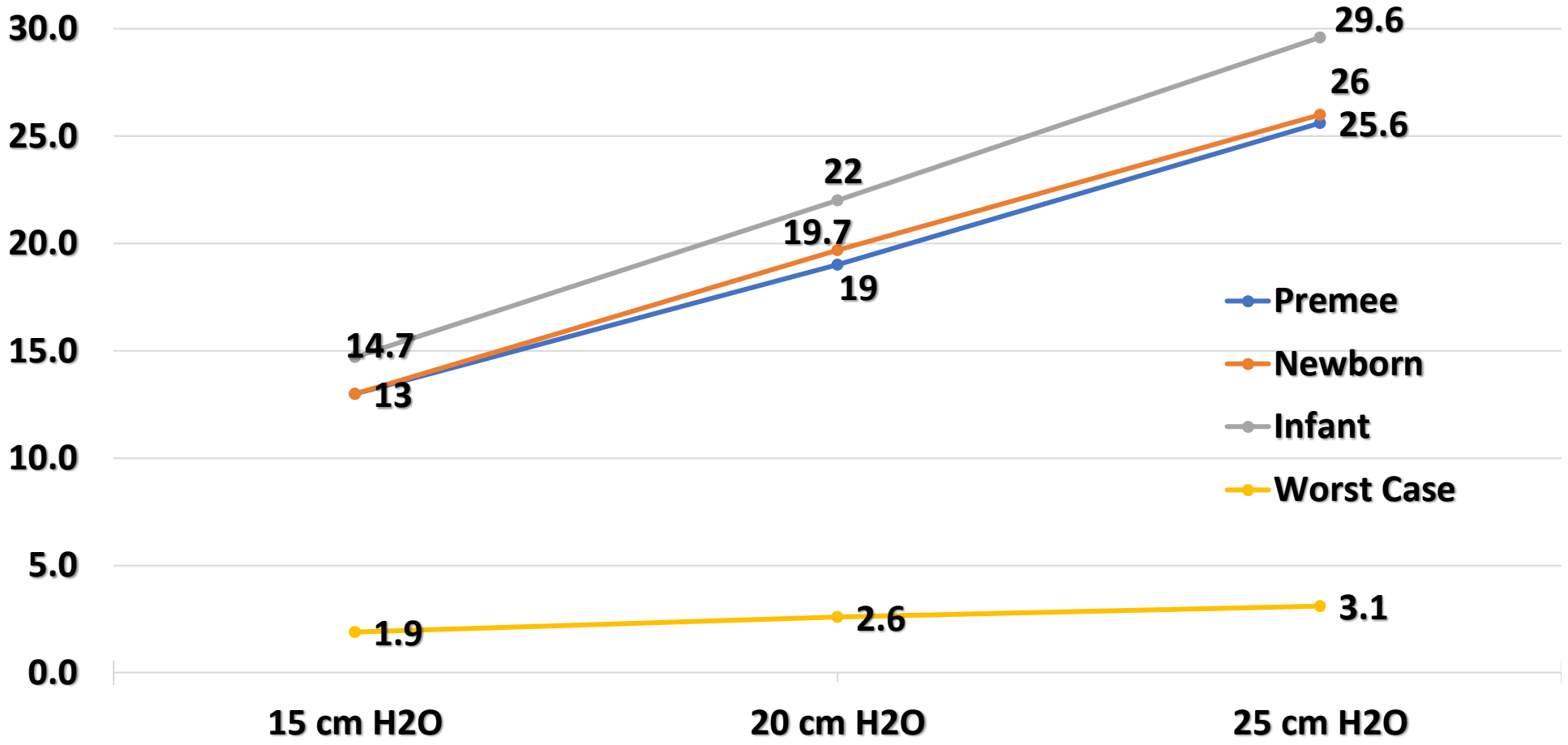
Narayan P Iyer, and Robert Chatburn Respir Care 2015;60:508-512

Measured PIP in a Simulate Nose at Different Set PIPs



Narayan P Iyer, and Robert Chatburn Respir Care 2015;60:508-512

Measured VT in a Simulate Nose at Different Set PIPs



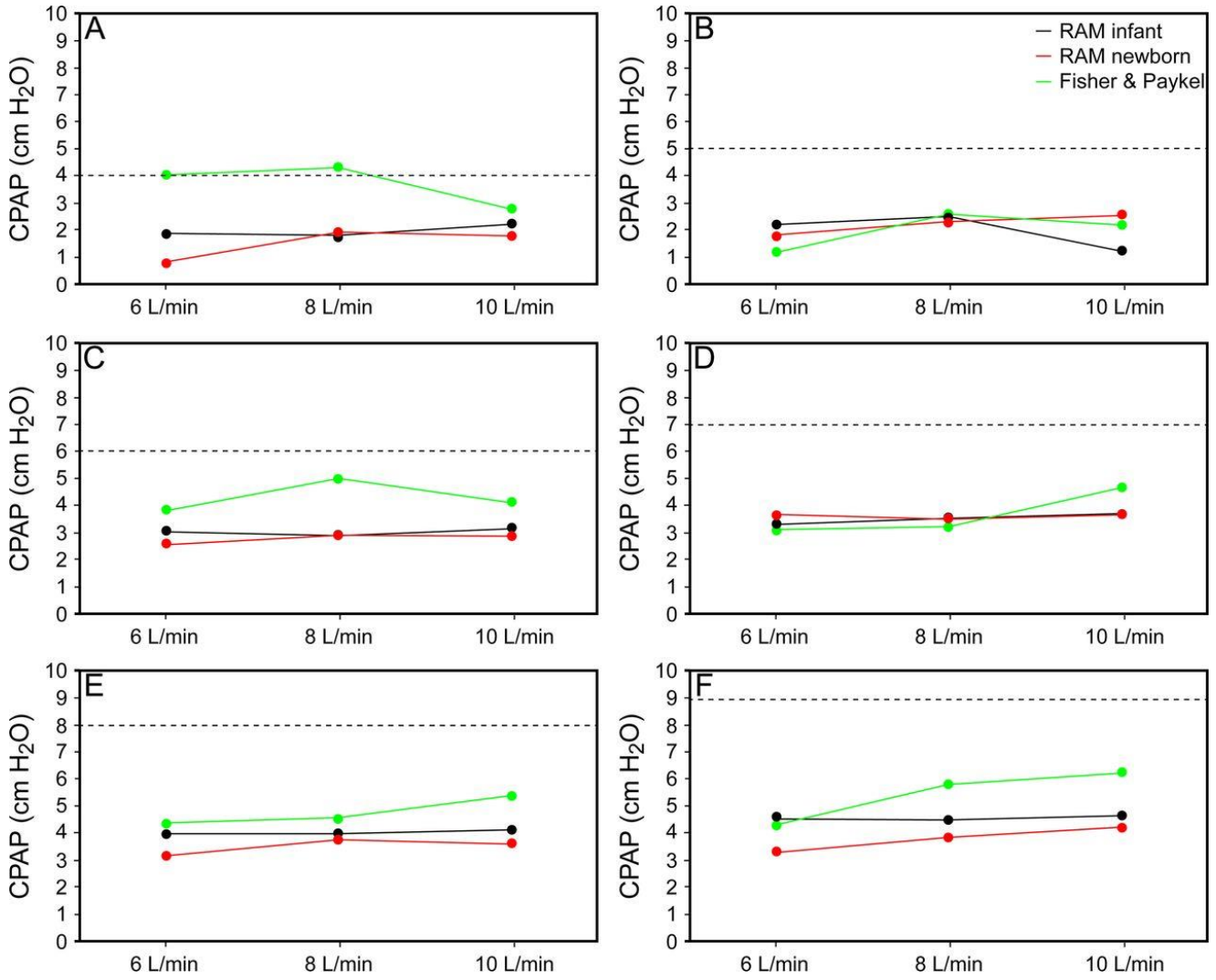
Narayan P Iyer, and Robert Chatburn Respir Care 2015;60:508-512

CONCLUSIONS

- With < 30% leak, the RAM cannula results in clinically acceptable transmission of pressures

- With > 50% leak, a clinically negligible amount of pressure is transmitted to the artificial lungs

Measured median CPAP levels for each set CPAP level across the range of flows



Stephanie A Bailes et al.
Respir Care 2016;61:333-9

Flow can either ↑ resistance to breathing or fail to meet inspiratory demands
Clinicians need to be aware of the effect of flow on CPAP delivery

RAM vs Classic CPAP Cannula for Non-Invasive Ventilation in Premature Babies
Prospective and Randomized Study of Non-Inferiority

Outcome Intubation ≤ 72 Hs	**N Total**	**Ram**	**CPAP Conventional**	95% CI of risk difference	*P*
Study Group	166	12/83 (14%)	15/83 (18%)	−14.8 to 7.6	.53
Brthweight, g					
<1250	82	7/42 (17%)	9/40 (23%)	−22.9 to 11.3	.51
≥1250	84	5/41 (12%)	6/43 (14%)	−16.2 to 12.6	.81
NIV Initial	104	10/53 (19%)	10/51 (20%)	−15.9 to 14.4	.92
Postextubation	62	2/30 (7%)	5/32 (16%)	−24.3 to 6.5	.43
Moderate & severe nasal trauma		4 (5%)	14 (17%)	0.02 to 0.22	**.01**

2 cases of severe nasal injury, both in the group of the classic CPAP interface

Hochwald O et al. JAMA Ped 2020

As HFNC

As HFNC


Cursor
16:14
29-Oct-2015
FiO₂ Vol%
30
FiO₂
30
Const. flow L/min
6
Const. flow
6
O₂ Therapy
30
FiO₂
6
Const. flow

Non-Invasive Nitric Oxide

Conventional NCPAP vs. Ram Cannula

	Conventional NCPAP	Ram cannula
Conection to ventilator	Desconnect 2 tubes	Direct Conection
Use in delivery room	Difficult	Easy
Use for transport	Difficult	Easy
Cleaning	Cloth cap	No accessories
Accidental Extubation	Slow Conection	Rapid conection
Patient's Motility	Restricted	Free
Injury to the Nasal septum	Frequent	Rare
Use of additional device	Some models	Ventilator
Control	Pressure	Pressure or Flow