WALTER O'DONOHUE LECTURE: HUMIDFIED HIGH FLOW CANNULAE OXYGEN THERAPY

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NICHOLAS S. HILL, MD, is Chief of the Division of Pulmonary, Critical Care and Sleep Medicine at Tufts Medical Center in Boston and Professor of Medicine at Tufts University School of Medicine. He received his M.D. from Dartmouth Medical School in 1975. He did his internship and residency in Medicine at Tufts-New England Medical Center. He did a fellowship in Cardiovascular Medicine at the University of Massachusetts Medical Center and in Pulmonary Medicine at Boston University School of Medicine. He is Board Certified in Internal Medicine, Pulmonary Diseases, and Critical Care Medicine. He has done extensive research and writing in the fields of noninvasive ventilation and pulmonary hypertension dating back over 30 years. He has edited several books related to these topics. He established the Pulmonary Hypertension Center at Tufts Medical Center. He is a Past President of the American Thoracic Society and has received a Distinguished Scholar Award in Critical Care from the Chest Foundation of the American College of Chest Physicians as well an Award for Excellence in Pulmonary Hypertension Care from the Pulmonary Hypertension Association. He has served on the Board of Directors of NAMDRC in the past and is an avid triathlete.

OBJECTIVES:

Participants should be better able to:

FRIDAY, MARCH 23, 2018 9:30 AM

Walter O'Donohue Lecture – Humidified High Flow Nasal Cannulae Oxygen Therapy

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Disclosures

- Research Grants
  - Fisher Paykel
- Advisory Board
  - Alung technologies
  - Fisher Paykel
- Consultant
  - Respironincs
  - ResMed
  - Vapotherm

Walter J O'Donohue MD (1934-2002)

- Charter member and Past President of NAMDRC
- Chair of Medicine, Creighton U Sch of Med
- Expert on Home Oxygen Therapy
- Indefatigable advocate for removal of barriers to care

Outline

- Technical Considerations
- Physiologic effects
- Compare and contrast with Standard Oxygen and NIV
- Clinical Applications
- Practical Considerations
- Knowledge gaps

What's in a name?

- HHFNCOT - Humidified High Flow Nasal Cannulae Oxygen Therapy
- HFNO – High Flow Nasal Oxygen
- HFNC – " " Nasal Cannula
- HFNT - " " Nasal Therapy
- HFN – High Flow Nasal
- NHF – Nasal High Flow

Technical Aspects

	NIV	NHF
Heat	Variable	31-34° C
Humidity	Variable	Saturated
Pressure	Pre-set insp and Exp	Variable
Flow	Variable	Continuous (20-60 L/min)
Circuit	Single or Double	Single-heated
Oxygen	Bled-in or blender	Blender (0.21-1)

Favorable aspects of NHF compared to Standard O2 and NIV include all except:

- Secretion mobilization
- Oxygenation
- Comfort and Tolerability
- Decreased nasal resistance
- None of the above

NHF: Heat and Humidification

- Dry gas at high flow cools, dessicates, causes constriction and is uncomfortable
- High flow gas conditioned to body temperature and saturation
- Enhances comfort and tolerability
- Reduces metabolic cost of breathing

HF: Heat and Humidification

- Loose-fitting comfortable interface
- Permits unimpeded speaking and eating
- Enhances tolerance

Comfort with NHF

20 pts with O2sat < 96% on FIO2 50%, 2 30 min periods

	Face Mask	NHF
Dyspnea	6.8	3.8*
Mouth dryness	9.5	5.0*
Overall Comfort	5.0	9.0*

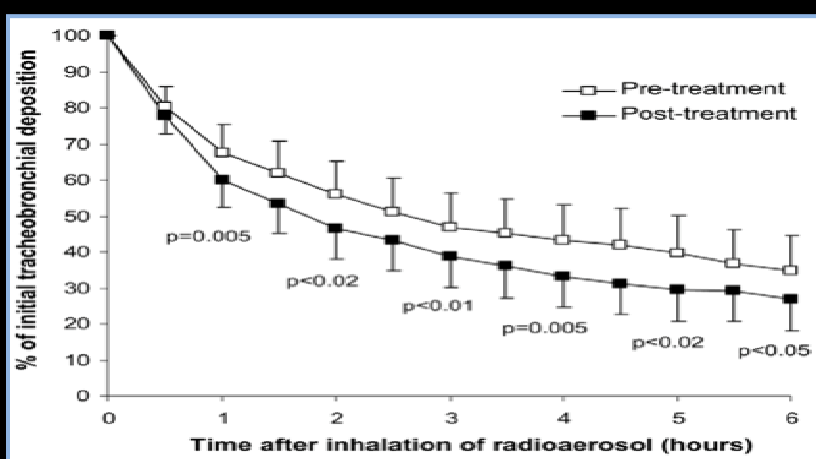
Roca O et al, Respir Care 2010

Secretion Mobilization

- One of first favorable effects posited
- Humidifies and loosens secretions
- Avoids dessication of airway
- Avoids bronchoconstriction caused by airway cooling
- Preserves mucociliary function
- Possible reduction in respiratory infections

Removal of Radioaerosolized Secretions

10 pts with bronchiectasis, 3 hrs daily for a week



Hasani A et al, Chronic Respir Dis 2008

Effective Oxygenation

- Peak inspiratory flow rate (PIFR) high in dyspneic patients with respiratory failure
- Standard oxygen systems provide flows of 10-15 l/min
- Leads to entrainment of room air and dilution of inhaled oxygen
- Using high inspiratory flow rates, NHF reduces entrainment of room air and maintains FIO2 closer to target

Effective Oxygenation

- Oxygenation also enhanced by washout of dead space in upper airway – first portion of inhaled gas is mixture at target FIO2, not exhaled gas with lower FIO2

Oxygenation with HF

20 pts with O2sat < 96% on FIO2 50%, 2 X 30 min periods

	Face Mask	HF*
FIO2 (%)	100 (?)	100
PaO2 (mm Hg)	77	127*
SpO2 (%)	95	98

Roca O et al, Respir Care 2010

These mechanisms contribute to ↓ work of breathing with NHF except:

- Reduced dead space
- Positive end-expiratory pressure
- Increased end expiratory lung volume (EELV)
- Reduced respiratory rate

Physiologic Study on NHF for Acute Hypoxemic Failure*

In 15 pts c/w standard O2 mask NHF:

- Lowered RR, minute volume, no change VT
- Decreased esophageal pressure swings
- Lowered pressure time product (PTP)
- No change in PaCO2
- Increased end expiratory lung volume (EIT**)
- Better homogeneity of V/Q

** Electrical impedance tomography *Mauri T, AJRCCM 2017

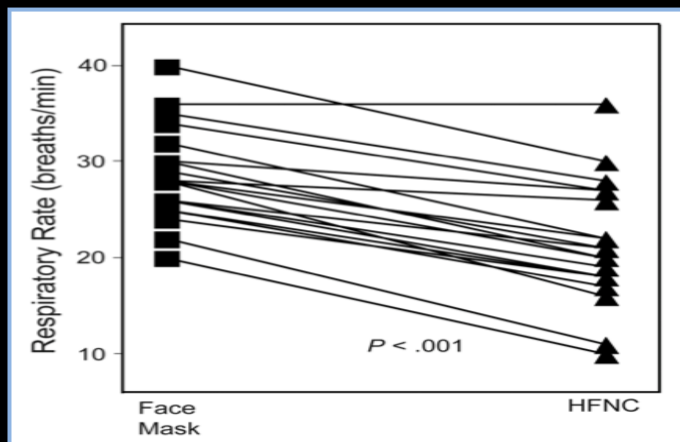
Enhancing Efficiency of Ventilation

- Washes out expired CO2 from upper airway before next inhalation
- Reduces dead space ventilation and VD/VT

Spence CJ et al Exp Fluids 2011

Reduced Work of Breathing:

WOB = RR X (Pr X Vol)/breath

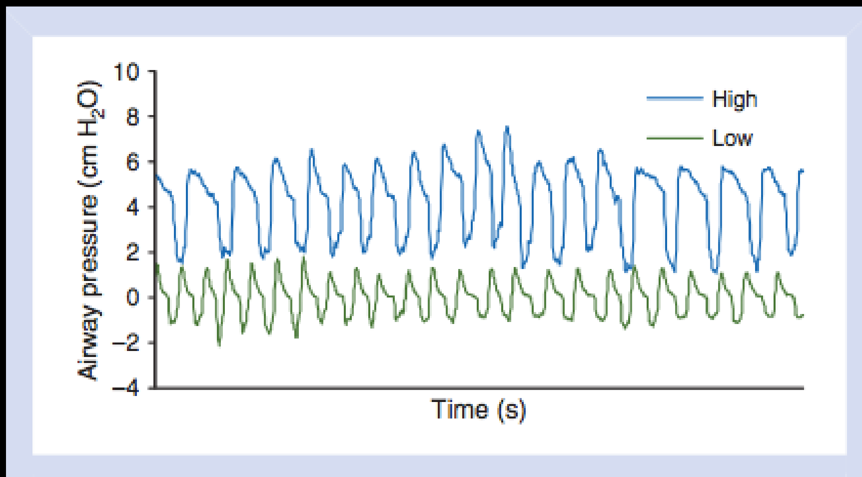


Roca O et al, Respir Care 2010

Less Breathing for Same Alveolar Ventilation = More Efficient

$$\downarrow V_E = \downarrow RR \times V_T = \downarrow V_D + V_A$$

Positive End Expiratory Pressure with NHF



Corley A et al, Brit J Anaesth 2011

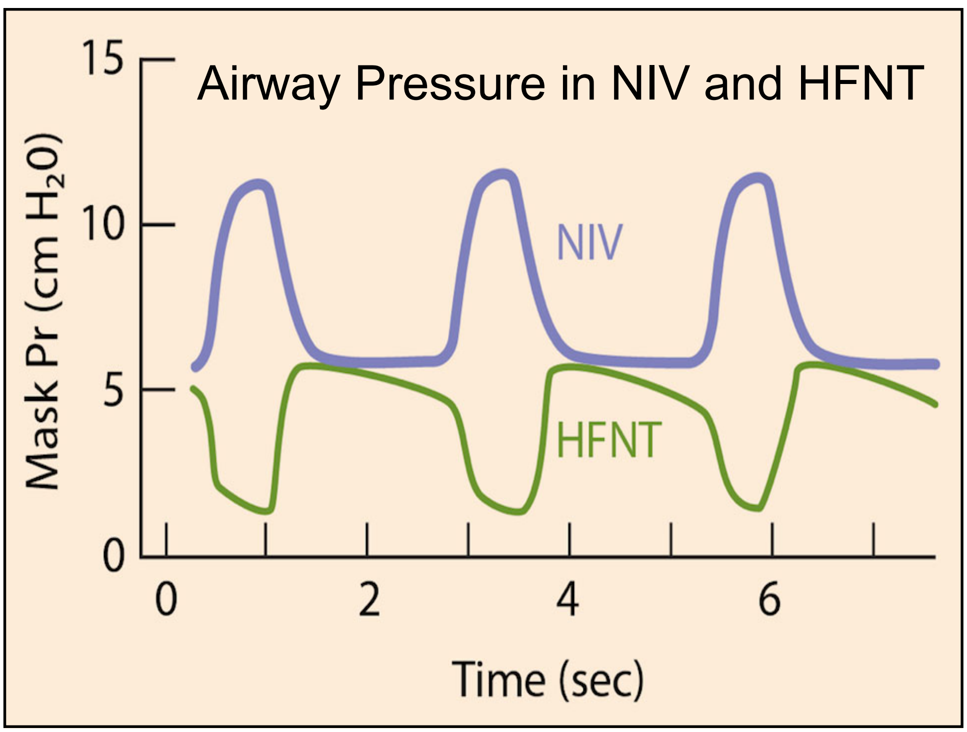
Positive End Expiratory Pressure with NHF – Effect of open mouth

	Nasal flow rate (L/min)				
	0	10	20	40	60
EPP (cm H_2O)					
Mouth open	0.3	0.7	1.4 [a]	2.2 [ac]	2.7 [a]
Mouth closed	0.8	1.7	2.9 [ab]	5.5 [ac]	7.4 [a]
IPP (cm H2O)					
Mouth open	-0.6	-0.2	-0.2 [a]	0.1 [a]	0.5 [a]
Mouth closed	-1.1	-0.8	-0.2 [a]	1.1 [ac]	1.6 [a]

Groves N, Tobin A. Austral Crit Care 2007

Physiologic Effects of NIV

- Expiratory pressure (or continuous) –
  - Increases FRC, improves oxygenation
  - Counterbalances auto-PEEP
- Inspiratory pressure support
  - Reduces inspiratory effort
  - Augments Tidal Volume
- Reduced WOB, improved gas exchange, reduced dyspnea and reversal of resp failure



Summary: HFNT Physiologic Effects

- Heated, humidified oxygenated gas with loose fitting nasal prongs renders HFNT more comfortable, tolerable
- Unimpeded speech and eating with HFNT
- HFNT enhances mucociliary clearance
- HFNT effective oxygenator – high insp flow, ↓ dead space
- HFNT clears dead space in upper airway; ↑ vent efficiency
- Reduces WOB/min largely by virtue of decreasing resp rate

Applications of NHF that are supported by evidence include:

- Hypoxemic respiratory failure
- Hypercapnic respiratory failure
- Post-extubation respiratory insufficiency
- Post-cardiac surgery respiratory insufficiency
- All of the above

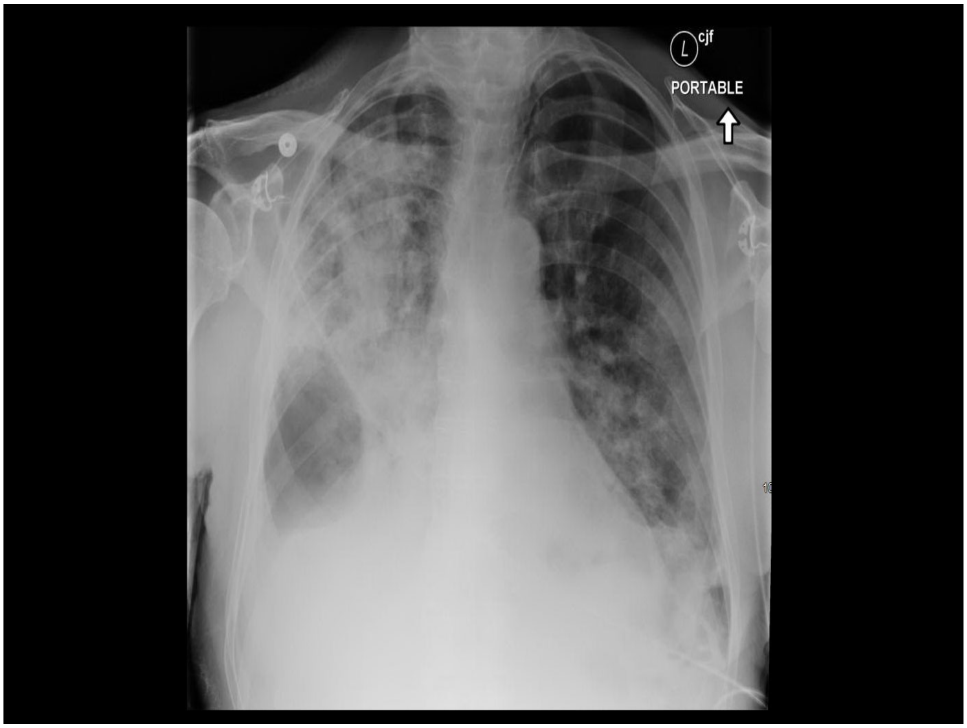
Clinical Applications of NHF

Supported by evidence (no guidelines)

- Hypoxemic Respiratory Failure
- Post-operative
- Post extubation
- Do not intubate
- Humidify secretions
- Endoscopy
- Acute Pulmonary Edema?
- Hypercapnic Respiratory Failure?

The Case of Mr B

- 74 yo former professional hockey goalie visiting family from his horse farm in TN.
- History of radical neck surgery, XRT for squamous cell CA of tongue; chronic aspiration
- Now presents with fever, cough, SOB.
- In ED, RR 38, O2 sat 51%, using access muscles, diffuse crackles posterior, Rt > Lt
- On 100% NRB, RR lo 30s, O2 sat 84%



You Would:

- Add standard nasal prongs at 6 l/min to 100% NRB
- Place on CPAP
- Place on BPAP (NIV)
- Place on NHF
- Intubate
- Transfer to another institution in a hurry

CPAP for Hypoxemic RF

123 pts with ALI (PaO2/FIO2 < 300) 21 cardiac

	CPAP (10 cm H20)	STD
n	62	61
1h P/F	203	151*
Intubated	34%	39%
ICU LOS (d)	6.5	6
Died	31%	30%
Adverse events	18	6*

Delclaux C et al, JAMA 2000; 284:2352

Acute Hypoxemic Respiratory Failure

- Italian multicenter study of 354 NIV cases, 30% failures; 50% ARDS or CAP, 10% cardiogenic pulmonary edema
- ARDS/pneumonia 3.75 times likelier to fail NIV than acute cardiogenic pulmonary edema

Antonelli et al, Int Care Med 2001 27:1718

NIV as "First Line" Therapy in ARDS

- 147 pts eligible of 479 (332 intubated), had dyspnea, RR > 30 and ≤ 2 new organ failures
- 54% avoided intubation –

  VAP rate 2 vs 20%, mortality 6 vs 53%
- Success more likely if SAPS II ≤ 34 and PaO2/FIO2 > 175 p 1st hr of NIV therapy

Observations on NIV Use in the LUNG SAFE study on ARDS

- International prospective study involving 459 ICUs in 50 countries
- Collected data on 2813 ARDS pts (P/F < 300) and new bilat infiltrates
- 507 (18%) managed with NIV
- Rate of use same in mild, mod, severe, but mortality 22%, 42% and 47%, respectively
- Propensity analysis showed in subgroup with P/F<150 mortality 36% v 25% in NIV v INV

Bellani G et al, JAMA 2016

Why is NIV so challenging for ARDS/Severe Hypoxemic RF?

- Severe O2 defect – more PEEP, more leak, desaturation if mask "falls off"
- Stiff lungs – Higher insp pressure, more leak, less comfort
- High minute volumes, tachypnea – harder to meet demands, synchronize
- Hard to tolerate
- Sick patients – sepsis, secretions, MODS, deteriorating

What about HFNO for AHRF? RCT of NHF v NIV v SO

- P/F ≤ 300, RR > 25, No PaCO2 > 45, no CRF
- 2506 pts with AHRF – 525 eligible - 313 enrolled
- Baseline RR 33/min, P/F 155, 75-80% PNA
- NRB ≥ 10 l/min, NHF 50 l/min, FIO2 1.0 (actual 82 %), NIV VT 7-10 ml/kg (actual PS 8, PEEP 5, FIO2 67%, VT 9.2 ml/kg), 8 hrs daily X 2d

Frat J-P et al, NEJM 2015

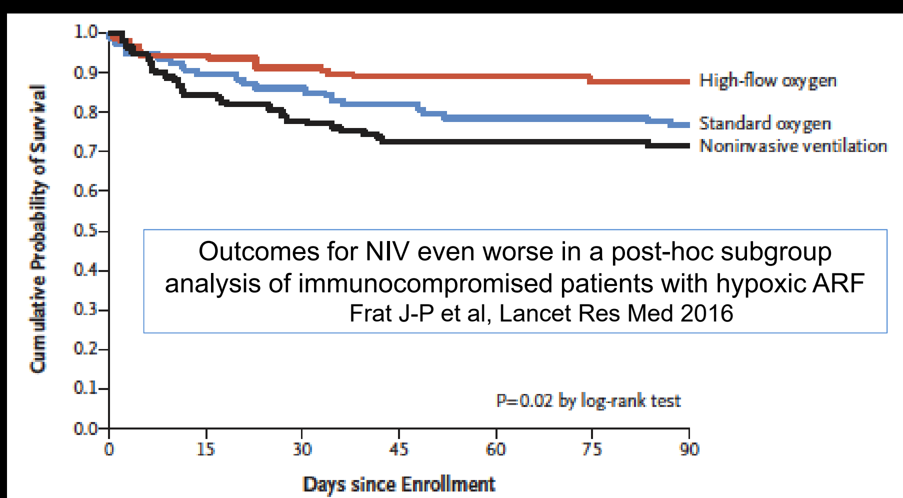
RCT of NHF v NIV v SO in AHRF

•	HFNO	SO	NIV
n	106	94	110
Intubation (%)	38	47	50
Intub P/F < 200	35	53	58*
Vent free days	24	21	18*
Death ICU (%)	11	19	25*
Death 90d (%)	30	45	49*

* P<0.05

Frat J-P et al, NEJM 2015

RCT of NHF v NIV v SO in AHRF



Frat J-P et al, NEJM 2015

Concerns re Frat Study

- NIV was actually 16hrs NHF, 8 hrs NIV for 1st 2 days
- Explanation for mortality difference?
  - Average VT 9.2 ml/kg during NIV (targeted)
  - More refractory shock in NIV group (6% v 17%)
- Impossible to blind

What about Mr B?

- Placed on CPAP 10 in ED, O2 sats 92%, RR 30s
- Switched to NHF, 50l/min 100% FIO2, O2 sat to 96%, RR hi 20s
- Weaned to 80% , 70% and 60% FIO2 next 4d
- Very comfortable and tolerated without difficulty
- Expectorated and cleared secretions well
- On day 5 FIO2 50%, 20l/min and converted to nasal prongs 6l/min

What about Mr B?

RCT Post Cardiac Surgery

- Hi Flow 50 l/min, O2 sat 50% v BiPAP 8 cm H20 IPAP, 4 EPAP at least 4 hrs daily
- 414 v 416 pts with failed SBT (P/F < 150) or failed extubation (P/F < 300, RR > 25, Access muscle use), BMI > 30 or LVEF < 40%.
- Treatment failure 1^{ry} outcome (reintubation or early discontinuation)
- BL RR 33, P/F 200, pH 7.39, PaCO2 39 mm Hg

Stephan F et al, JAMA 2015

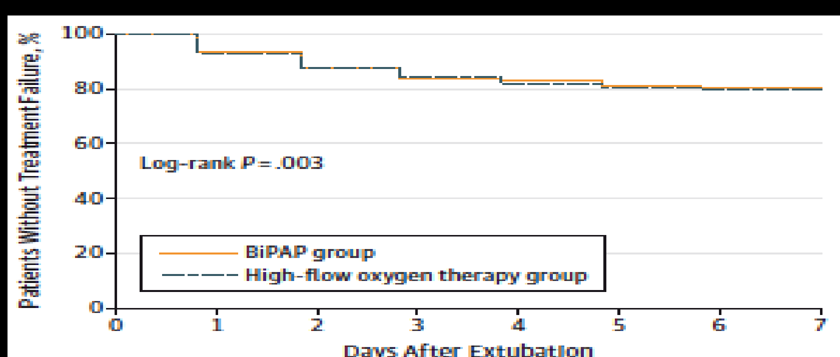
RCT Post Cardiac Surgery

	NHF	BiPAP
n	414	416
Settings (l/min; cm H2O)	46.7	9.3/4.2(VT 7.2)
RR	26.7	29.7
Reintub (%)	14.0	13.7
Crossovers (%)	10.8	7.9
PaO2/FIO2	157	187*
Hrs /day	20	6.5*

Stephan F et al, JAMA 2015

RCT Post Cardiac Surgery

Pts without Treatment Failure



No diff Comfort or Dyspnea, Mortality (6.8 v 4.8%), Focal erythema (9.4 v 2.5%) Stephan JAMA 2015

HNFO for Post-extubation

- 105 pts passed SBT with P/F ≤ 300, 3/4 with pneumonia, trauma or atelectasis
- Randomized to HFNO (50 l/min) or venturi mask adjusted to maintain SaO2 ≥ 92%
- 1ary outcome P/F ratio at 24 hrs
- BL RR 23 PaO2 91, P/F 241
- Reintubations 4% (HFNO) vs 21% (venturi)*

Maggiore SM et al, AJRCCM 2014

NHF for Post-extubation

- Maggiore SM et al, AJRCCM 2014
  - 105 pts, Reintubations 4% (HFNT) vs 21%* (Venturi)
- Hernandez G et al, JAMA 2016 (Low risk)
  - 440 pts, Reintubations 14% (HFNT) vs 37%* (SO)
- Hernandez G et al, JAMA 2016 (High risk)
  - 604 pts, Reintubations 19% (NIV), 23% (HFNT)

RCT of HFNO v SO in “low-risk” Post Extubations Pts

- 440 pts (<65 yrs; APACHE II <12; BMI <30; secretions manageable; ≤1 comorbidity
- Baseline P/F 230, ¾ postop or neurological
- Reintubation within 72 hrs; 4.9% v 12.2%*
- Reasons for reintub: inability to clear secretions: 3 (14%) v 14 (37%)*
  - Hernandez G et al, JAMA 2016

NHF for Do-not Intubate pts

- Greater comfort than standard high flow oxygen
- Allows speaking and eating po
- Among 183 pts with CA, 85% tolerated and improved or remained stable

Epstein AS et al, J Pall Medicine 2011

HFNO for Cardiogenic Pulm Edema

- Cohort series - inconclusive
- Personal observation
- PS and PEEP may be important – is it enough with HFNT?

A Role for HFNO in Hypercapnic Respiratory Failure (COPD)?

- Flushes dead space, improves ventilatory efficiency
- Enhances secretion mobilization
- Extrinsic PEEP to counterbalance auto-PEEP
- Decreases resp rate, more time for exhalation, lower WOB/min*; may avoid resp muscle fatigue
- Sequential use of NIV and NHF

*Pisani L et al, Thorax 2017

High Velocity Nasal Insufflation v NIV in the ED (noninferiority)

5 EDs, > 18 yrs, need for NIV, excl drug OD, cardiovasc, secretions, uncoop; COPD 25%, CPE 21%, AHRF/PNA 30%
Settings: HVNI: 30 l/min, FIO2 62%, temp 35
NIV: IPAP 13 , EPAP 5 cm H2O

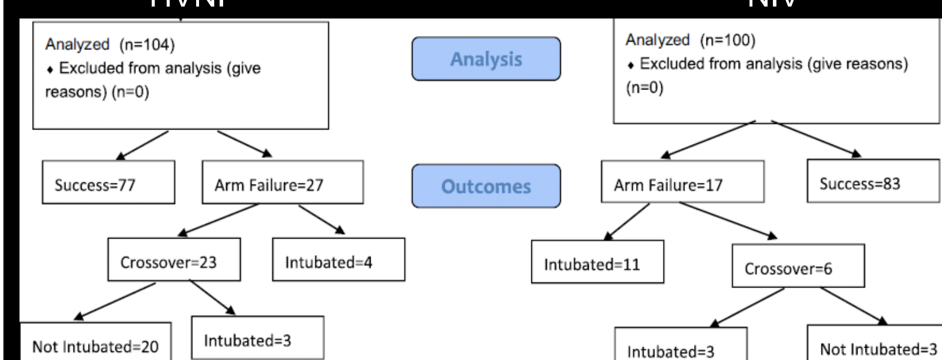
Group	HVNI	NIV
n	104	100
RR/min	31	29
SaO2 (%)	93	94
PaCO2 (mm Hg)	53	59
Therapy Failure (%)	26	17

No diff PaCO2 over time, Vital Signs, Lengths of stay, Discomfort, Borg dyspnea.

Doshi et al, Ann Emerg Med 2017

High Velocity Nasal Insufflation v NIV in the ED (Arm Failure)

HVNI NIV



Failure to:	HVNI	NIV
Oxygenate	3	0
Ventilate	12	6
↓ Distress	10	1

Doshi et al, Ann Emerg Med 2017

When to start HFNT?

Hypoxemic Resp Failure

- When standard O2 (NC 6l/min) is incapable of maintaining desired oxygenation (O2sat ≥ 90%)

Secretion retention, postextubation, postoperative

- Inspissated secretions, risk factors

HFNT: Practical Considerations

- What flow? Take advantage of high flow – dead space washout, greater effect on rate, higher PEEP
  - Start with 50l/min, adjust to comfort
- What heat? Some find 37° too hot, 34° may be preferable in those
  - Start with 37°, adjust to comfort
- What FIO2? Make sure flow is adequate first, then adjust FIO2.
  - Start at 100% if very hypoxic, lower if not
- How to wean?
  - Lower FIO2, then flow. Transition to NC at 20-30l/min, 50% FIO2

Summary: HFNT for ARF

- HFNT preferred to NIV in mild to moderate Hypoxemic RF– severe not tested
- May be helpful postop for humidIfication, secretion mobilization, not inferior to NIV in post-cardiac surg, ED pts
- Role in post-extubation, do-not intubate pts
- ? Other applications; cardiogenic pulm edema, trauma – results fom RCTs are awaited – COPD not yet tested in RCT

What role for HFNT?

Hypoxemic Respiratory Failure

SO_2 HFNOand/orNIV? Intubation ECMO

Hypercapnic Respiratory Failure

SO_2 HFNO? NIV ECCO2R? Intubation

Mild Severe