Surgery Grand Rounds

Non-invasive Ventilation:
A valuable tool

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8/24/09

History of mechanical ventilation

- 1930's: use of iron lung
- 1940's:
  - First NIV system (Bellevue Hospital)
- 1950's: Polio epidemic
  - Positive pressure ventilation with tracheostomy
- 1980's
  - NIV used in COPD
- 1990's
  - Increasing use of NIV in non-COPD settings
- 2000's
  - NPPV standard of care for COPD exacerbation

Pierson. Resp Care 2009

Terminology

- NIV – No evidence supporting one specific type of NIV
  - Mask vs nasal
    - Nasal equally effective in increasing FRC
      - » More comfortable, allows communication, less claustrophobia
  - Helmet
  - CPAP
  - NPPV = PSV + PEEP





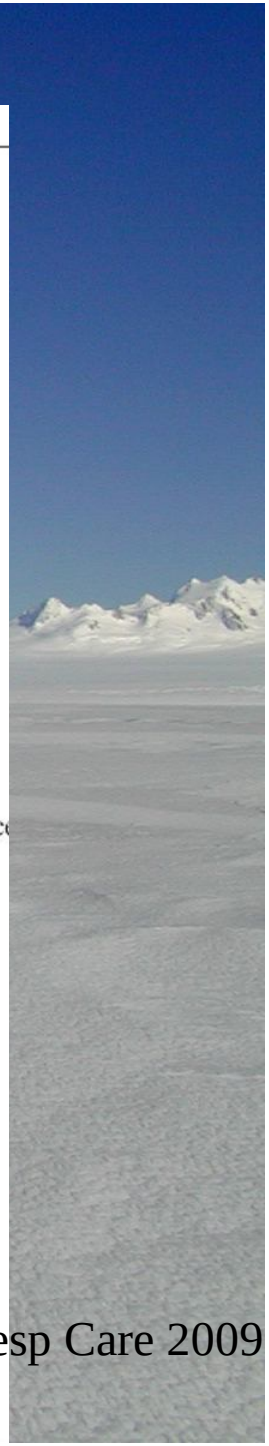


Benefits of NIV

- Reduced infectious complications
  - Multiple PRCT evidence
- Earlier extubation in COPD patients
- Potential avoidance of endotracheal intubation
- Avoidance / reducing need for sedation

Risks of NIV

Problem	Incidence	Remedies
Nasal mask		
Mask discomfort	30–50%	Decrease strap tension Re-seat mask Try different mask size or type
Skin rash	10–20%	Topical steroids or clindamycin Dermatologic consultation
Nasal-bridge sores	5–10%	Minimize strap tension Use forehead spacer Artificial skin Switch to different mask type
Nasal obstruction	Occasional	Topical decongestant Try oronasal mask
Oronasal mask		
Mask discomfort	30–50%	Minimize strap tension Try different mask size or type
Claustrophobia	10–20%	Reassure patient Try different mask type
Skin rash, nasal bridge sores	10–20%	Same as for nasal mask sores
More dead space	Depends on mask	Insert foam rubber to reduce dead space Anti-asphyxia valve
Aspiration of vomit	Rare	Quick-release straps
Mouthpiece		
Discomfort	Common	Reassure patient Diminishes with adaptation
Hypersalivation, salivary retention	Common	Reassure patient Diminishes with adaptation
Aerophagia	Common	Reassure patient Simethicone
Pressure sores on lips, gums	Infrequent	Decrease strap tension Consider custom fitting
Orthodontic problems	After prolonged use	Remodel mouthpiece Consult orthodontist
Head straps		
Discomfort	10–30%	Try different strap system
Unstable mask	Common with 2-strap system	Try different mask or strap system



Gay. Resp Care 2009

NIV for AECOPD

Study/Year	Patients, No.		Mean $PaCO_2$, mm Hg		Failures, No. (%)†		
	NPPV Group	Control Group	Pre-NPPV	Post-NPPV*	NPPV Group	Control Group	p Value
Bott et al[7]/1993	30	30	65	55	3 (10)	9 (30)	0.014
Kramer et al[8]/1995‡	16	15	74	67	5 (31.1)	11 (73.3)	< 0.05
Brochard et al[9]/1995‡	43	42	70	68	11 (25.6)	31 (73.8)	< 0.001
Angus et al[10]/1996	9	8	76	65	0 (0)	3 (37.5)	Not given
Celikel et al[11]/1998	15	15	69	64	1 (6.6)	6 (40)	< 0.05
Plant et al[12]/2000	118	118	66	61	18 (15.3)	32 (27.1)	0.02
Barbe et al[13]/1996	14	10	59		4 (28.6)	0 (0)	Not given

- 1a evidence:
  - Reduces intubation rates
  - Reduced mortality rate (25 → 9%)
  - Reduced hospital stays
- Aspiration events very infrequent

→ **NPPV considered first line therapy in this scenario`**

Plant, et al. Thorax 2001

Acute Cardiogenic Pulmonary Edema

- 1a evidence, Multiple metanalyses and RCT's:
  - CPAP and NPPV lower intubation and mortality rates compared to O2 therapy
  - CPAP should be initial choice for CPE management

Immunocompromised patients

- 1a evidence
- Reduced mortality rate (50 vs 81%) in immunocompromised ARF patients receiving NIV vs. supplemental O2

ARDS

- Lacking PRCT's
- No benefit demonstrated with NIV in ARDS
- Antonelli et al, Crit. Care Med 2007:
  - Prospective observational study
    - 147 ARDS patients treated with NPPV
      - 53% avoided intubation
      - Significantly reduced hospital mortality and VAP compared to those intubated

NPPV vs ETI in ARF

- PRCT: 64 pts. with hypoxemic ARF (medical / surgical)
  - Inclusion:
    - P/F < 200, RR > 35, accessory muscle use
    - PNA, Trauma, Surgical (thoracic, vascular, orthopadic, GI), cardiogenic pulm. edema
  - Exclusion:
    - COPD
    - hemodynamic instability
    - Immunosuppressed
    - neurologic disease
    - > 2 organ system failure
    - Facial deformity.
    - Recent oral, esophageal, **or gastric surgery**
  - Intervention:
    - NPPV up to 10cm H2O, to maintain Vt 8-10 cc/kg and FiO2 <60%
  - Conversion to ETI:
    - Failure to maintain PaO2 > 65 mmHg
    - Need for airway protection (altered mental status, copious secretions
    - Hemodynamic instability

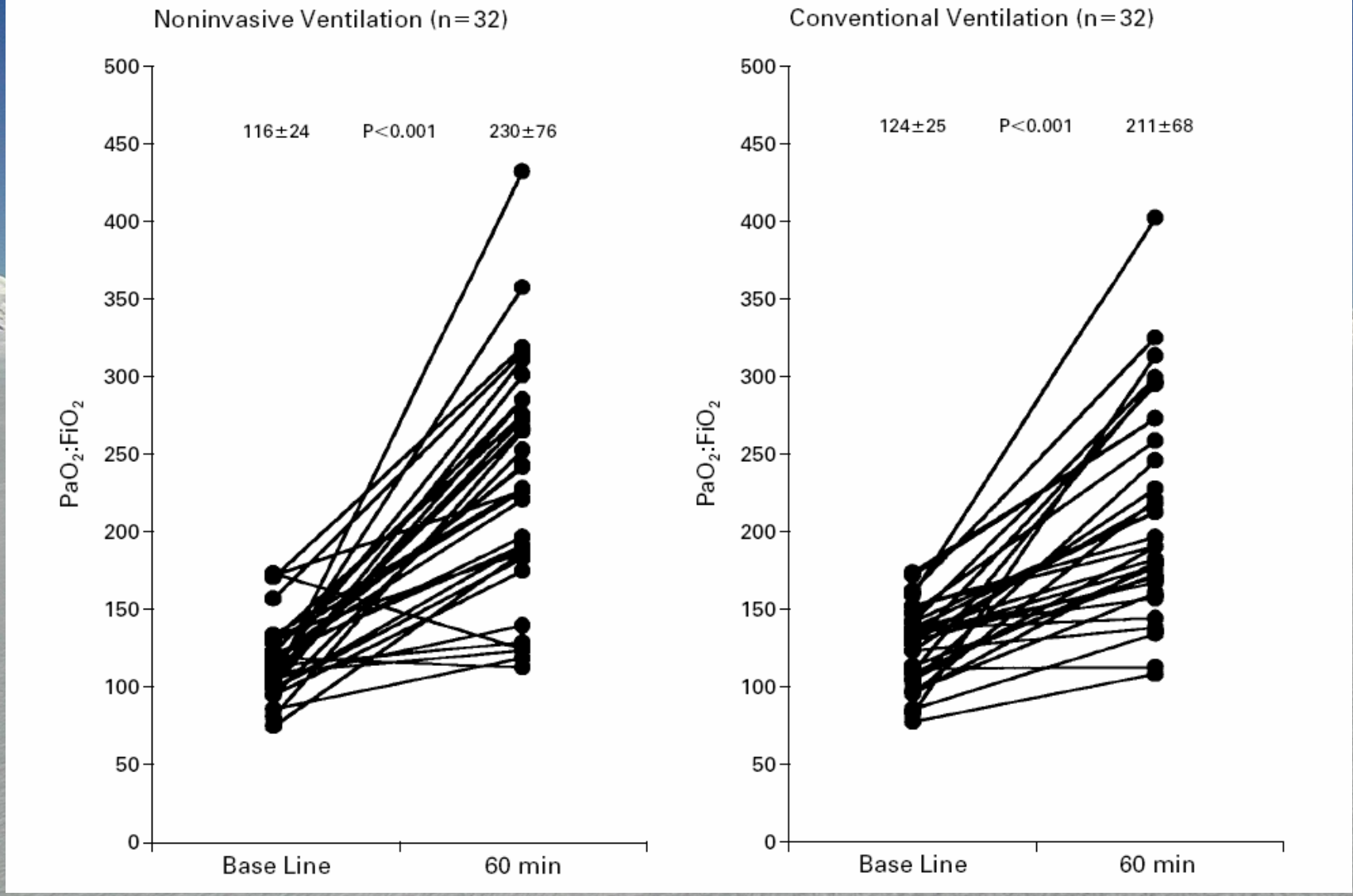
Antonelli, et al. NEJM 1998

Variable†	Noninvasive-Ventilation Group (N=32)	Conventional-Ventilation Group (N=32)
Patients' characteristics		
Age — yr	52±19	57±18
Male sex — no. (%)	18 (56)	20 (62)
SAPS	13±4	12±4
Heart rate — beats/min	100±21	110±17
Respiratory rate — breaths/min	39±4	39±5
Body temperature — °C	36.8±0.7	36.8±0.6
Systolic blood pressure — mm Hg	135±28	132±29
Arterial pH‡	7.45±0.1	7.37±0.1
$PaCO_2$ — mm Hg	38±9	42±11
$PaCO_2$ >45 mm Hg — no. (%)§	5 (16)	12 (38)
PaO_2:FiO_2	116±24	124±25
Causes of acute respiratory failure — no. (%)		
Pneumonia	5 (16)	4 (12)
Trauma	4 (12)	4 (12)
Cardiogenic pulmonary edema	7 (22)	5 (16)
Postoperative respiratory failure¶		
Acute respiratory distress syndrome‖	7 (22)	9 (28)
Mucous plugging or atelectasis	7 (22)	9 (28)
Gastric-contents aspiration without acute respiratory distress syndrome	2 (6)	1 (3)

55% surgical / trauma patients

Antonelli, et al. NEJM 1998

P/F similar in NIV compared to conventional ventilation



Antonelli, et al. NEJM 1998

Caveat: Ventilator time

- •NIV failure:15 d
- •NIV success: 2
- •Control: 6

VARIABLE*	NONINVASIVE-VENTILATION GROUP (N=32)	CONVENTIONAL-VENTILATION GROUP (N=32)
Patients with complications — no. (%)†	12 (38)	21 (66)
Patients with complications causing death in ICU — no.	9	15
No. of complications per patient‡	1.3	1.7
Death after discharge from ICU — no.	1	1
Complications — total no./no. causing death in ICU (% of group)§		
Myocardial infarction or cardiogenic shock	2/2 (6)	4/4 (12)
Sepsis¶	6/5 (19)	11/6 (34)
Renal failure	3/0 (9)	5/0 (16)
Pancreatitis	1/0 (3)	1/1 (3)
Polyneuropathy of the critically ill	0/0	1/0 (3)
Pneumonia‖	1/0 (3)	8/2 (25)§
Sinusitis‖	0/0	2/0 (6)
Pulmonary embolism	0/0	1/1 (3)
Massive blood loss	0/0	1/1 (3)
Infection at study entry**	2/2 (6)	0/0

P= 0.003

- •**Results**:
  - •Success: 69% avoided ETI
  - •Decreased PNA & sinusitis rate
    - •3% vs 31% (P = 0.003)
      - •1 patient who failed NPPV
      - •No NPPV patients
- •Trend toward reduced mortality and ICU stay in NIV group

Antonelli, et al. NEJM 1998

Chest Trauma

- RCT (1990):
  - Fewer complications and shorter hospital stay for NIV + epidural compared to ETI
- PRCT (2005): 43 pts, flail chest:
  - CPAP vs ETI (both with IV sedation): trend toward lower rate pulmonary complications
    - Lower hospital mortality 9% vs 33% (NS)

Gunduz, et al. Emerg. Med J. 2005

Post-operative use of NIV

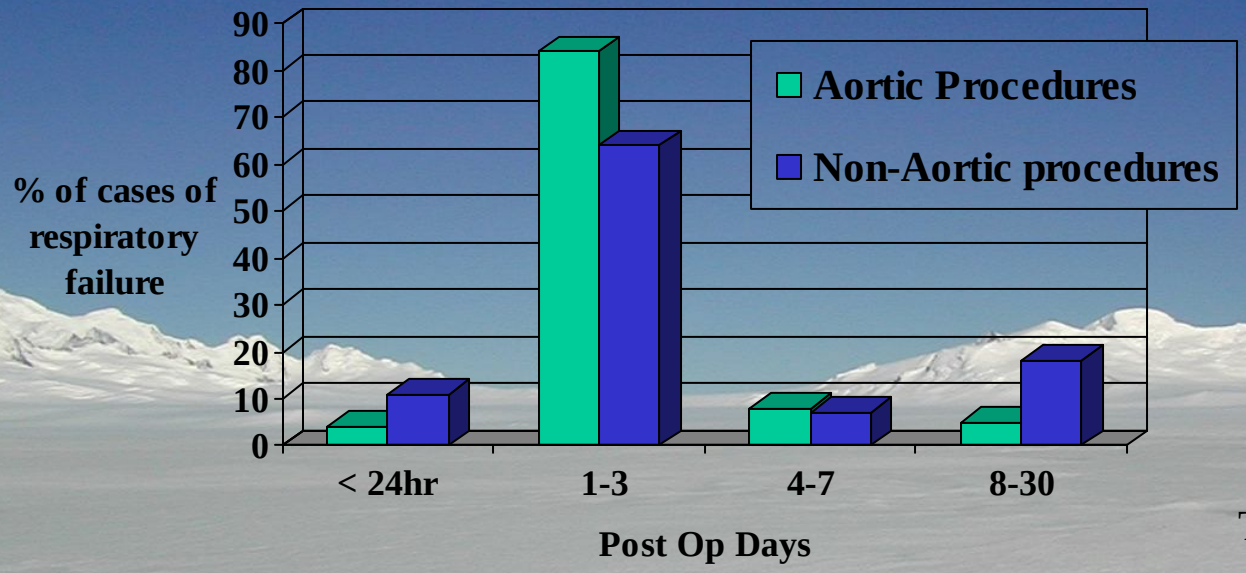
Significance of reducing Extubation Failure

- Extubation failure
  - SICU: 3 – 6%
  - MICU 12 – 19%
  - 7 X increase in mortality, or 30-40% in hospital mortality in pts requiring re-intubation

Epstein, et al. Chest 1997

Study (Year)	Patient Type	No. of Patients	% Reintubated	% Mortality
Sahn et al (1973)[5]	MICU/SICU	100	17.0	NR
Hilberman et al (1976)[8]	Cardiac surgery	124	17.7	NR
Tahvanainen et al (1983)[6]	MICU	47	19.0	22.2
DeHaven et al (1986)[10]	SICU/trauma	48	6.3	NR
Demling et al (1988)[1]	General SICU	400	5.5	40.0
	Burn/trauma unit	300	3.3	10.0
Krieger et al (1989)[7]	MICU/SICU	269	10.4	NR
Sassoon et al (1993)[11]	MICU	40	12.5	NR
Mohsenifar et al (1993)[12]	RICU	29	14.3	NR
Lee et al (1994)[3]	MICU	52	17.0	33.3
Brochard et al (1994)[9]	MICU/SICU	109	11.0	NR
Torres et al (1995)[2]	MICU/SICU	170	23.5	35.0
Esteban et al (1995)[4]	MICU/SICU	530	15.7	NR
Current study	MICU	289	14.5	42.5

Postoperative respiratory failure: VA database



Thompson, et al. Arch Surg. 2003

15 VA centers, 2003:

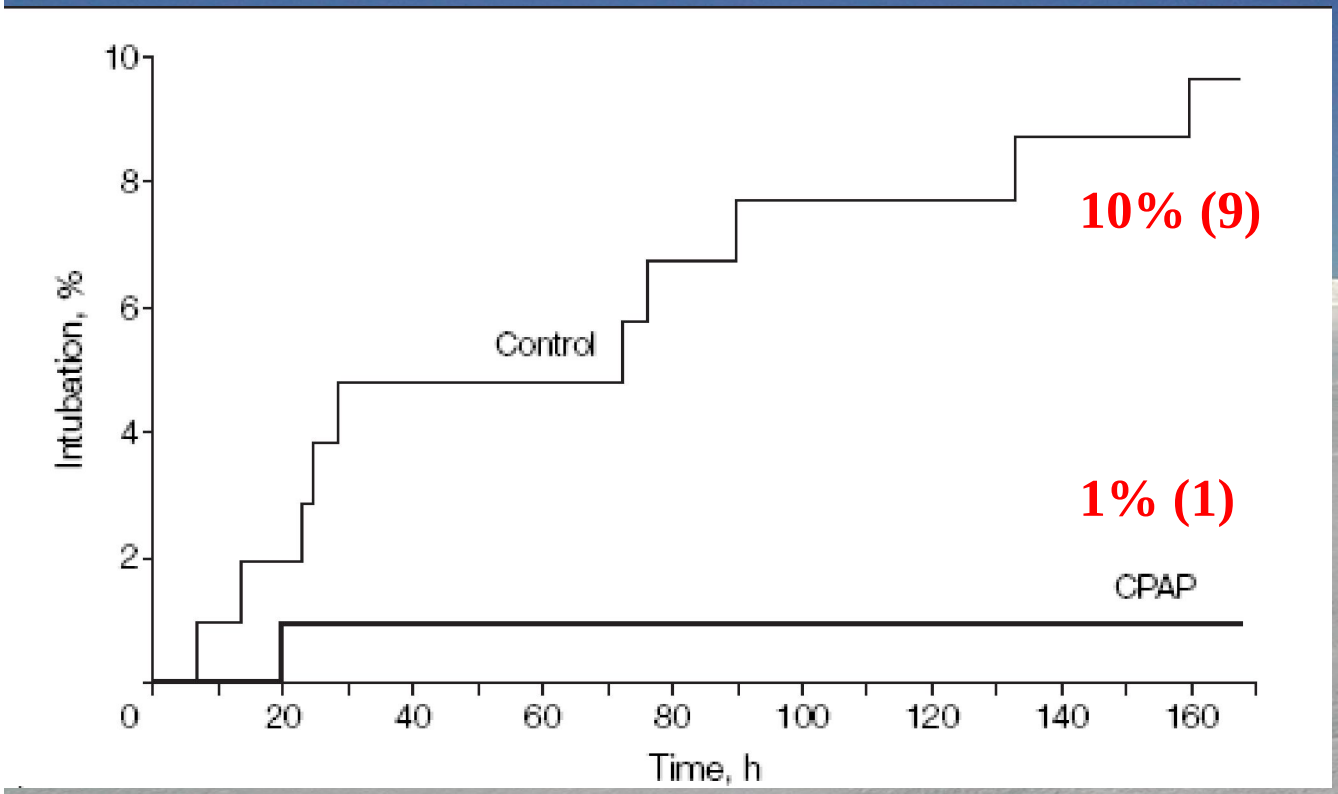
- 1021 men undergoing major abdominal surgery
  - ASA III, IV; 32% with COPD; 38% smokers
- **12% overall respiratory failure (intubation > 24 hrs or re-intubation post-op)**
  - (23% aortic, 7% non-aortic cases)

Major elective abdominal surgery

- Multicenter, RCT: CPAP vs standard O2
- 209 patients, post-op ARF:
  - Inclusion:
    - ARF P/F <300 (1 hr post-op, on FiO2 30%)
    - Laparotomy > 90 minute viscera exposure
      - Whipple, gastrectomy, colectomy, hepatectomy, liver transplant, retroperitoneal mass resection
    - < 80yrs old
  - Exclusion:
    - Cardiac disease (MI, CHF), or recent cardiac / aortic surg.
    - **COPD / asthma**
    - BMI > 40, h/o infection, immunocompromised state
    - Shock, ARDS, albumin < 3 g/dL, Cr > 3.5mg/dL, Hgb <7 g/dL, **pH < 7.3**
  - Intervention:
    - Venturi mask (FiO2 50%) vs. CPAP at 7.5cm H2O

Squadrone, et al. JAMA 2005

Major elective abdominal surgery



P= 0.005

NNT: 11

Indication for intubation:

- $SaO_2 < 80\%$
- $pH < 7.3$, $pCO_2 > 50$
- Patient distress
- GCS <9
- Cardiac arrest
- Hemodynamic instability

Compare to published re-intubation rate:

5 – 19% in SICU / Trauma settings

Squadrone, et al. JAMA 2005

Major elective abdominal surgery

	Control (n = 104)	CPAP (n = 105)	Difference of Means (95% CI)	*P* Value*
ICU length of stay, mean, d	2.6	1.4	–1.2 (–2.0 to –0.3)	.09
Median (95% CI), d	1 (1-11)	1 (1-4)		
Hospital length of stay, mean (SD), d	17 (15)	15 (13)	–2 (–6 to 2)	.10
Median (95% CI)	12 (7-47)	11 (6-35)		
			Relative Risk (95% CI)	
Pneumonia, No. (%)†	10 (10)	2 (2)	0.19 (0.04 to 0.88)	.02
Infection, No. (%)‡	11 (10)	3 (3)	0.27 (0.07 to 0.94)	.03
Sepsis, No. (%)§	9 (9)	2 (2)	0.22 (0.04 to 0.99)	.03
Anastomotic leakage, No.	6	1		
Pneumonia, No.	3	1		
Deaths, No. (%)	3 (3)	0 (0)		.12

- Significant reduction in PNA and nosocomial infections
- Mortality rate not significantly affected

Post-cardiac surgery

- 468 CABG and Valve replacement patients
  - Exclusion: EF < 40%, periop MI, post-op pressors, severe COPD, or if intubated > 18 hrs post-op.
  - Randomized to nasal CPAP or Venturi mask + iCPAP (10” q 4hr)

- CPAP at 10 cm, **at least 6 hrs**. (15hrs)
  - Controls received intermittent CPAP 10minuts q4hr

- Reduced pulmonary complications (PNA, reintubation, P/F <100):
  - 5% vs 10% complication rate in NPPV vs control (P=0.03)
    - 1.3% vs 2.5% reintubation rate

Zarbock, et al. Chest 2009;135:1252 (Germany)

Thoracoabdominal Aortic Repair

- 50 patients randomized to standard O2 or nCPAP post-extubation
- Intervention:
  - 12-24 hr nCPAP (10cm H20) immediately following extubation

Re-intubation rate:

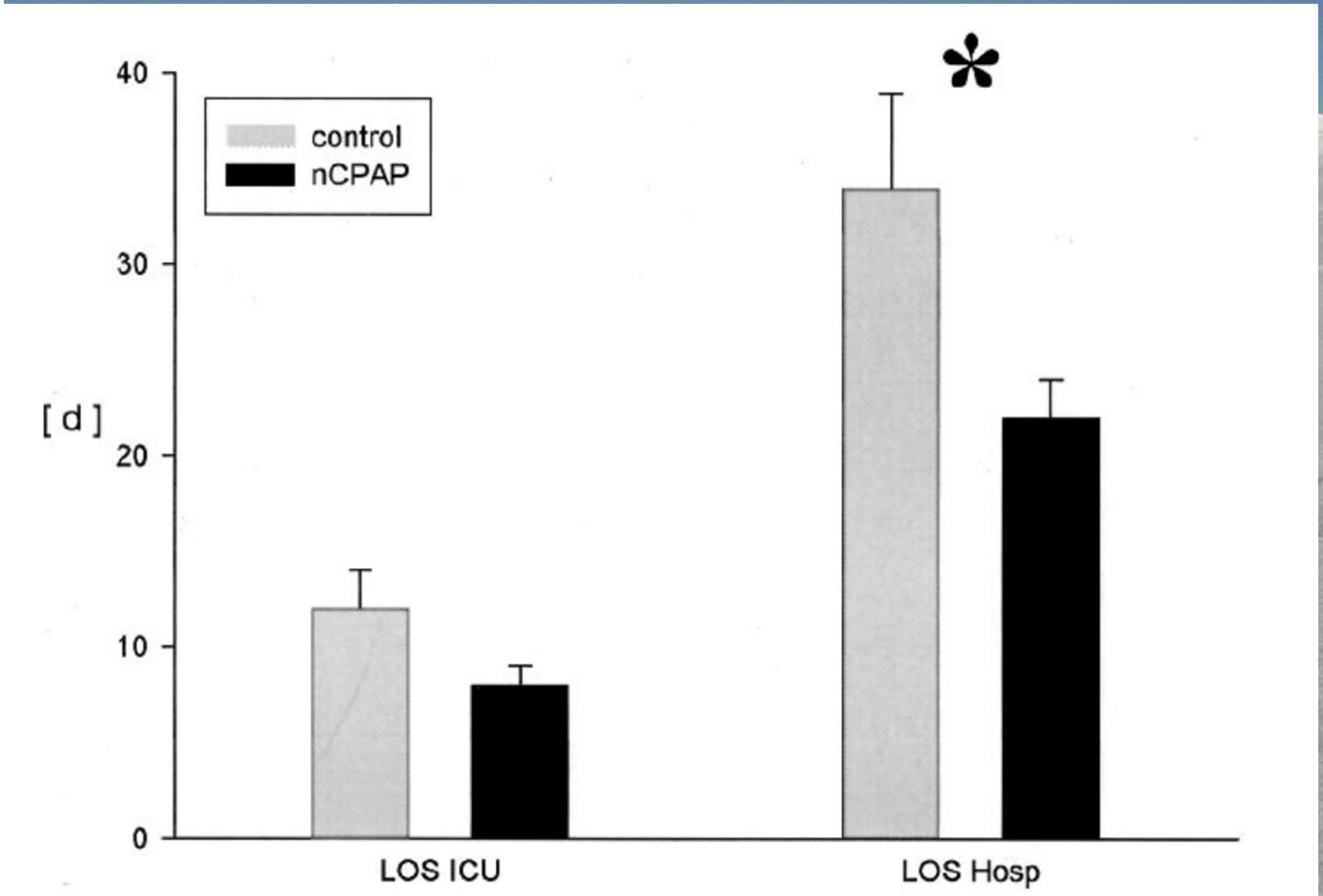
4 vs 16%

No mortality data given

Complications	nCPAP Group (n = 25)	Control Group (n = 25)	p Value
Pulmonary complications	7	24	0.019
Pneumonia	0	3	
Atelectasis	2	5	
$PaO_2/FIO_2 < 100$	4	12	
Reintubation	1	4	
Cardiac complications	4	8	NS
Myocardial infarction	0	1	
Cardiac arrhythmia	4	7	
Acute renal failure	1	3	NS
Postoperative delirium	5	4	NS

Kindgen-Milles, et al. Chest 2005;128:821

Thoracoabdominal Aortic Repair



- Hospital LOS reduced by 12 days in nCPAP group (P<0.05)

Kindgen-Milles, et al. Chest 2005;128:821

NPPV in post-operative transplant recipients

- 5% PNA rate in transplant recipients
  - Crude mortality rate of 37%
  - ETI most important predisposing risk factor for PNA

NPPV for post-op ARF in solid organ transplant recipients

- PRCT: N=40
  - Liver, Lung, Kidney transplants
- Inclusion
  - ARF: P/F < 200, RR > 35, accessory muscle use
- Control: Venturi Mask, FiO2 > 40%
- Intervention: NPPV, PEEP up to 10cm H2O
  - Target Vt 8-10cc/kg
  - Continuously applied
- ETI criteria:
  - Failure to maintain PaO2 > 65 mmHg
  - Copious secretions, poor airway protection

Antonelli et al. JAMA 2000

NPPV in solid organ transplant

- Mean duration of NPPV: 50hrs
- Lower re-ntubation rate: 20% vs 70% (P=0.002)
  - Majority intubated within 24 hr of randomization
- Significantly lower rates of
  - Septic complications
  - Fatal complications
  - ICU mortality
- Insignificant trend toward fewer PNA in NPPV group (not adequately powered)

Antonelli et al. JAMA 2000

Post-lung resection

- PRCT, N = 48: NPPV vs. supplemental O2
  - S/p lobectomy, bilobectomy, pneumonectomy
  - ARF: P/F < 200, RR > 25
  - Exclusion: upper airway obstruction, copious secretions, agitation, hemodynamic instability, MOF
    - Level of consciousness and pH not considered
- NPPV, Vt 8-10 cc/kg
  - Continuous application, avg. 2.1 days
    - 14 hr NPPV per day.
- Results:

	Mortality (120 d)	Re-intubation rate
NPPV	12.5% (P=0.045)	21% (P=0.035)
No NPPV	37.5%	50%

Auriant, et al. AJRCCM. 2001

	Subject profile	Intervention	Baseline : PaCO2 (mmHg) pH	Pulmonary Complication (%)	PNA (%)	Mortality (%)	Treatment failure (%)
Esteban NEJM 2004	N = 221 **Post-extubation failure** (25% surgical/trauma)	CPAP vs Supplemental O2	47 7.39			**25 vs 14 (P = 0.048)**	**48 vs 47 (NS)**
Ferrer AJRCCM 2003	N = 105 **ARF** (PaO2<60) (40% trauma or surgical)	BiPAP: 16/7 cmH2O (84hr) vs Venturi mask	37 7.42		10 vs 24 (NS)	**20 vs 39 (P=0.025) (90 day)**	**13 vs 28 (P=0.01)**
Antonelli NEJM 1998	N=64 **ARF** (P/F <200) (55% surgical)	NPPV (15hr) Vt: 10cc/kg vs **ETI**; Vt 10cc/kg	38-42 7.37-7.45	**3 vs 31 (P=0.003)**		31 vs 50 (NS)	31%
Squadrone JAMA 2005	N = 209 **ARF** (P/F < 300) Major abd. Surgery	CPAP (19hr) vs Venturi Mask (22hrs)	39 7.39		**2 vs 10 (P=0.02)**		**1 vs 10 (P=0.005)**
Kindgen-Milles Chest 2005	N = 50 Thoracoabdominal aortic repair	**Immediate** nCPAP (22 hr) vs Venturi Mask w IMV 10” q4hr		**28 vs 96 P=0.019**	0 vs 12		4 vs 16
Zarbock Chest 2009	N = 500 Cardiac surgery	**Immediate** nCPAP (9-16hr) vs Venturi mask + IMV 10” q4hr		**5 vs 10 P=0.03**	.4 vs 2.1		1.2 vs 2.5
Auriant AJRCCM 2001	N = 48 ARF (P/F < 200) Lung resection	NPPV; Vt: 8-10 cc/kg Vs Supplemental O2	38 – 44 7.38-7.42			**12.5 vs 37.5 (P = 0.045)**	**21 vs 50 (P=0.035)**
Antonelli JAMA 2000	N= 40 **ARF** s/p Transplant	NPPV (50hr) vs Venturi mask	38 – 42 7.43		10 vs 20	**20 vs 50**	**20 vs 70**

Conflicting trials

- Esteban, et al. NEJM 2004:
  - Multicenter PRCT, N=221.
  - NNVP for post-extubation failure
    - Compared mask to CPAP
  - Reintubation rate: 48% vs 47%
  - Mortality rate: 24% vs 14%
- Problems:
  - Only 25% surgical or trauma patients
  - Average ventilator time prior to extubation failure and randomization: 7 days
  - ARF definition (**P/F < 160 vs 200 –300**, **PaCO2 > 45**)
  - Interrupted NVVP (pt.s allowed to drink and discontinue for 20 minutes at a time)

Predicting NPPV Failure

- 1033 COPD exacerbation patients treated with NPPV
  - 77% avoided intubation
  - Post-operative patients excluded
- Predictors of failure for COPD patients:
  - APACHE score
  - pH
  - RR
  - GCS

Confalonieri, et al. Eur Resp. J 2005;25:348

Predictors at admission and at 2 hrs

		pH admission <7.25		pH admission 7.25–7.29		pH admission >7.30	
	RR	APACHE ≥29	APACHE <29	APACHE ≥29	APACHE <29	APACHE ≥29	APACHE <29
GCS 15	<30	29	11	18	6	17	6
	30–34	42	18	29	11	27	10
	≥35	52	24	37	15	35	14
GCS 12–14	<30	48	22	33	13	32	12
	30–34	63	34	48	22	46	21
	≥35	71	42	57	29	55	27
GCS ≤11	<30	64	35	49	23	47	21
	30–34	76	49	64	35	62	33
	≥35	82	59	72	44	70	42

2 hrs after NPPV initiation

		pH after 2 h <7.25		pH after 2 h 7.25–7.29		pH after 2 h ≥7.30	
	RR	APACHE ≥29	APACHE <29	APACHE ≥29	APACHE <29	APACHE ≥29	APACHE <29
GCS 15	<30	72	35	27	7	11	3
	30–34	88	59	49	17	25	7
	≥35	93	73	64	27	38	11
GCS 12–14	<30	84	51	41	13	19	5
	30–34	93	74	65	28	39	12
	≥35	96	84	78	42	54	20
GCS ≤11	<30	93	74	65	28	39	12
	30–34	97	88	83	51	63	26
	≥35	99	93	90	66	76	40

When to consider NPPV?

- Medical indications:
  - COPD exacerbation
  - Immunosuppressed
  - Cardiogenic pulmonary edema
  - DNR / DNI patients
- Surgical patients at risk of re-intubation
- Prophylactic post-extubation use in thoracoabdominal aortic and cardiac patients

Contraindications for NPPV

- Cardiac or respiratory arrest
- Inability to protect airway, high risk of aspiration
  - Upper airway obstruction
  - Encephalopathy
- Severe GI bleed
- Facial surgery or trauma
- Severe hemodynamic instability / **shock**
- Multiple organ failure
- ALI / ARDS with severe hypoxemia or acidosis

Summary of data

Level 1 evidence

Systematic reviews (with homogeneity) of RCTs and individual RCTs (with narrow CIs)

Evidence of use (favourable)

- COPD exacerbations
- Facilitation of weaning/extubation in patients with COPD
- Cardiogenic pulmonary oedema
- Immunosuppressed patients

Evidence of use (caution)

- None

Level 2

Systematic reviews (with homogeneity) of cohort studies—individual cohort studies (including low quality RCTs; eg, <80% follow-up)

Evidence of use (favourable)

- Do-not-intubate status
- End-stage patients as palliative measure
- Extubation failure (COPD or congestive heart failure) (prevention)
- Community-acquired pneumonia in COPD
- Postoperative respiratory failure (prevention and treatment)
- Prevention of acute respiratory failure in asthma

Evidence of use (caution)

- Severe community acquired pneumonia
- Extubation failure (prevention)

PRCT's of surgical patients:

- reduction in pulmonary complications and PNA
- reduction in re-intubation rates compared to standard therapy


Thank You