Cleaning Up the Trainwreck: The Critical Care Patient Going to the OR

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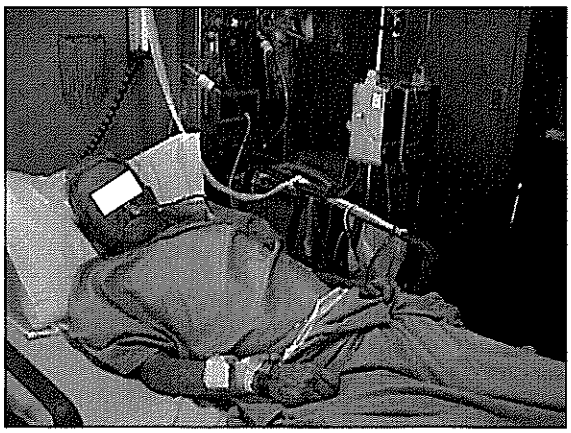
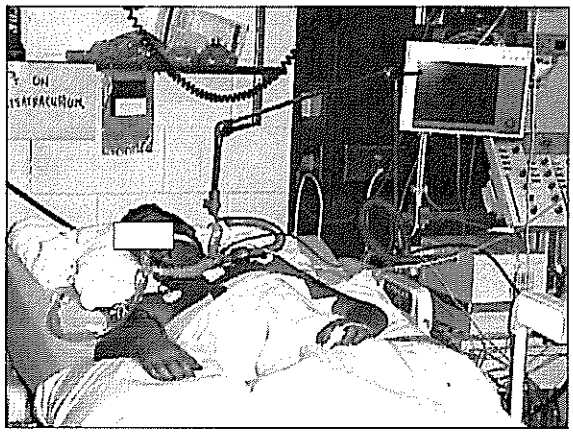
Case Study

☹ It's now 5 pm and you get the dreaded call there is an emergency case for an exploratory lap that needs to go now !





Case Study

- 58 y.o. male with firm, distended abdomen and severe metabolic acidosis (lactate- 5.0) coming to OR for exploratory laparotomy
- Vent Settings: Pressue Control - 34 Peep- 12 R- 24, FiO2= 100%, PiP- 46
- ABG: 7.20 / pCO_2 - 50 / pO_2 - 65
- CXR- reveals 3 quadrant infiltrates
- HR 110, BP 75/40, C.I. - 4.0 SVR- 458
- Drips: vasopressin and fenaldopam
- U/O - 5 cc last hour

Overview

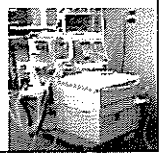
Discuss challenges the critically ill patient coming to the OR creates...with focus on recent advances in:

1. ARDS and Ventilation in the OR
2. Support of the Circulation
3. Electrolytes/Nutrition
4. Transport/Intraoperative Clinical Pearls

Ventilation of the Critically Ill Patient in the OR

(Not all ventilators are created equal !)





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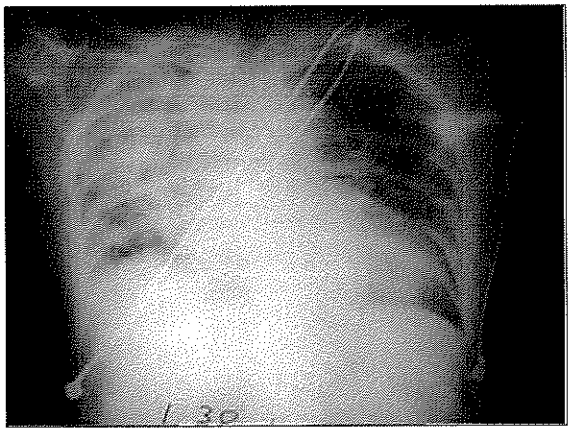


Diagnosis ?

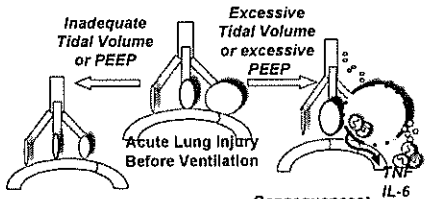

Acute Respiratory Distress Syndrome

- ✓Tachypnea, dyspnea, crackles
- ✓Diminished Compliance (< 40 cc/cm H_2O)
- ✓Impaired Gas Exchange (P_a0_2/FiO_2 < 200)
- ✓Diffuse airspace infiltrates on CXR
- ✓Exclusion of High Pressure Pulmonary Edema

New Strategies for ARDS/ALI Management

- Low tidal volumes for ALI/ARDS
  - ARDS network, NEJM 2000
  - 31.0% mortality versus 39.8% (NNT = 11)

Balancing Ventilation Priorities



Consequences:
- Atelectasis
- Hypoxemia
- Hypercapnia

Consequences:
- V/Q mismatch
- Alveolar-capillary injury
- Inflammation
- Pulmonary hypertension
- "Barotrauma"

Ventilator Management

- Assist control mode
- Reduce TV to 6 mL/kg predicted body weight
- Keep plateau airway pressure <30 cm H_2O
- Maintain SaO_2 / SpO_2 88%-95% using this scale:

FiO_2	.3	.4	.4	.5	.5	.6	.7	.7	.7	.8	.9	.9	.9	1.0
PEEP	5	5	8	8	10	10	10	12	14	14	14	16	18	20-24

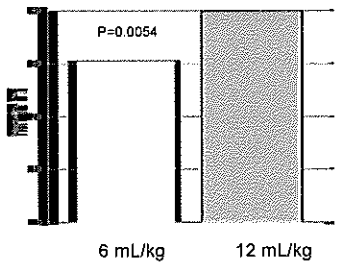
The Acute Respiratory Distress Syndrome Network. *N Engl J Med* 2000;342:1301-8

Ventilator Management

- Accept mild respiratory acidosis
  - If pH <7.30 increase rate (max 35)
  - If acidosis persists and rate = 35, consider $NaHCO_3$
  - If acidosis refractory/unresponsive, may raise TV to achieve pH >7.15

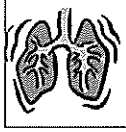
The Acute Respiratory Distress Syndrome Network. *N Engl J Med* 2000;342:1301-8.

Mortality Prior to Discharge

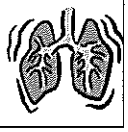


The Acute Respiratory Distress Syndrome Network. *N Engl J Med* 2000;342:1301-8

Can Your Anesthesia Machine Adequately Ventilate and Oxygenate This Patient ?



...Not Likely..!



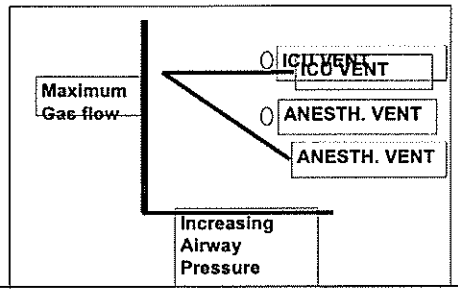
Shortcomings of Anesthesia Machines

- Most ventilators are equivalent in ventilating normal patients
- Problems arise as patients lung mechanics become abnormal (↑ flow requirements or peak airway pressures)
- Two parameters must be understood....

Shortcomings of Anesthesia Machines

1. Maximum gas flow: speed at which gas can be delivered to the lung
   - Higher gas flows allow sufficient tidal volumes to be delivered even with short Inspiratory times (I.e. ↑ respiratory rate)
2. Stability of gas flow: particularly with increasing airway pressure
   - As airway pressure increases most anesthesia machines experience a decrease in flow rate..thus TV must decrease

Shortcomings of Anesthesia Machines

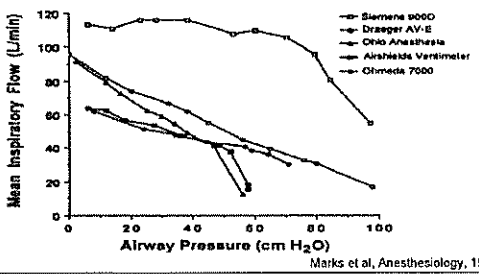


Shortcomings of Anesthesia Machines

- Although both ICU ventilators and anesthesia ventilators are powered by the same electrical and gas source....
- ICU ventilators are significantly better at:

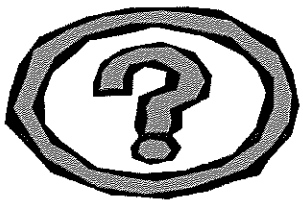
1. Delivering high gas flows
2. Maintaining high gas flows under high airway pressure conditions

Performance Comparison of ICU and Anesthesia Ventilators



Marks et al, Anesthesiology, 1989

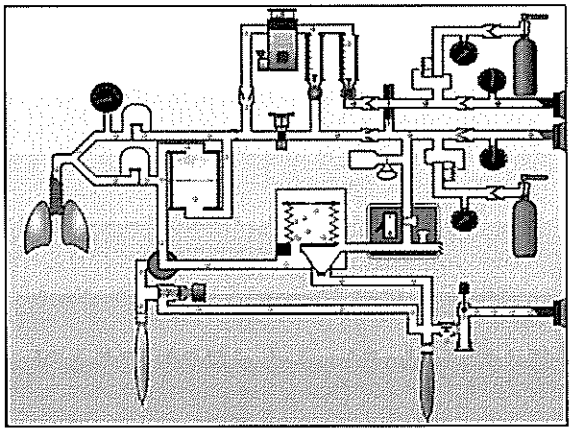
Why ?



Differences: ICU vs. Anesthesia Ventilators

- Anesthesia ventilators have a large internal volume (CO_2 absorber, bellows, exc...)
- Increased circuit volume leads to increased compliance → at high airway pressures much of the flow and volume is lost in circuit-

☹Thus, it never reaches the patient !!



Differences: ICU vs. Anesthesia Ventilators

- Internal Volumes:
  - Anesthesia Vent - 2000 - 4000 cc's
  - ICU Ventilator - < 100 cc's
- Peak Flow Rates:
  - Anesthesia Vent - 50 L/min
  - ICU Ventilator - 180 L/min

Differences: ICU vs. Anesthesia Ventilators

- What does this mean ?

1. Limits the maximal tidal volume delivered for any particular respiratory rate
2. Decreased tidal volume as airway pressure increases (Think-- increased afterload on a failing heart)

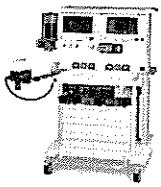
Differences: ICU vs. Anesthesia Ventilators

- This leads to progressive hypercarbia, respiratory acidosis, and hypoxemia

- Can only be corrected by switching to a ventilator capable of handling the increased pressure
- This means an ICU ventilator or a "newer" anesthesia machine

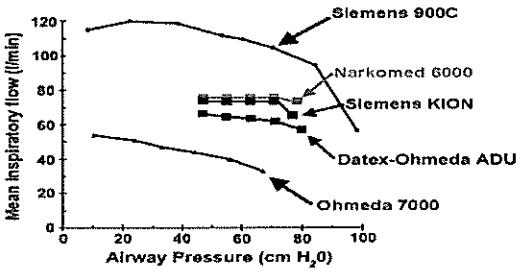
New Anesthesia Machines

- Include:
  - Narkomed 6000
  - Siemens
  - Siemens Kion
  - Datex-Ohmeda ADU
  - Datex-Ohmeda ADU



- These machines have:
  - Smaller CO2 absorbers and bellows
  - Improved "drive gas" mechanisms

New Anesthesia Machines



So..When Should I be Afraid My Ventilator May Fail ??

- When the sum of:

Peak Inspiratory Pressure (PiP) + Respiratory Rate= 60

i.e.-

PiP = 50	RR = 10
PiP = 40	RR = 20
PiP = 30	RR = 30
PiP = 20	RR = 40

So..When Should I be Afraid My Ventilator May Fail ??

- Any PiP > 50 cm H_2O
- Inspiratory Flow Rate > 50 L/min
- Peep > 10
- Increased A-a gradient (PaO_2/FiO_2 < 100)
- Significant Expiratory Disease (autopeep)

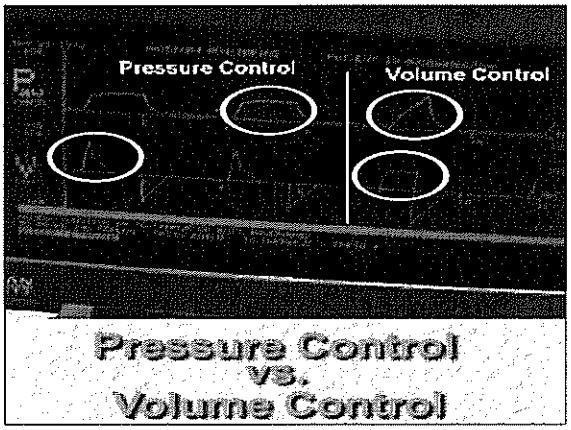
So..Could We Ventilate the Patient in Our Case ??

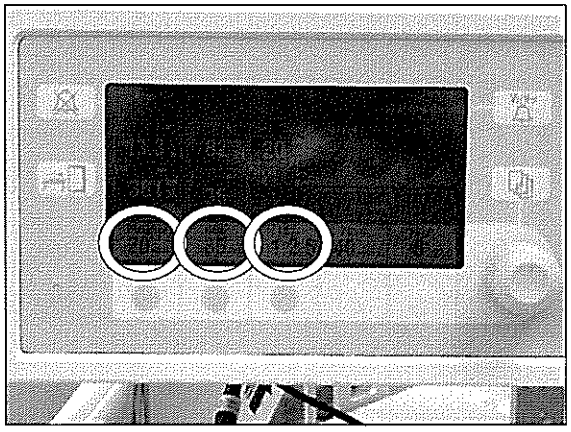
- Again, not likely... because...

1) PiP + RR = 46 + 24 = 70
2) Peep > 10
3) PaO_2/FiO_2 < 100

What about the patient on Pressure Control Ventilation ?

- Most anesthesia machines ventilate in volume control
  - Set Volume, Set Rate
  - Flow rate is fixed
  - ☹ Thus.. the machine can not compensate for changes in compliance easily


Pressure Control
Volume Control
Pressure Control
vs.
Volume Control



What about the patient on Pressure Control Ventilation ?

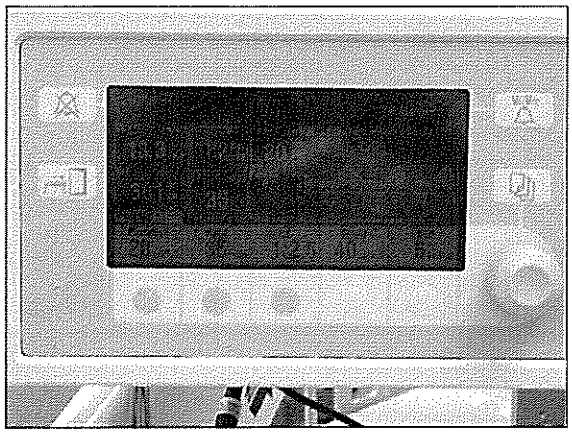
- Pressure Control allows ventilator to continuously vary flow rate to deliver a set pressure for a set inspiratory period
  - Set peak pressure, inspiratory time (or I/E ratio), respiratory rate
- Key Point: Tidal Volume will change as patient lung compliance changes !!
- Tidal Volume is not set !!
- Thus... one has to be extra vigilant in a patient on pressure control

Pressure Control: practical points

- Choosing Starting Pressure: Find plateau pressure (inspiratory pause pressure) for desired tidal volume (TV) in volume control mode
- Use that pressure as your starting pressure
- Pay close attention to your I_{time}- longer I_{time} will give larger TV and...

Pressure Control: practical points

- Shorter I_{time} will decrease tidal volumes
- Particularly important in anesthesia machines that have pressure control modes
- Anesthesia machines (except the Siemens Kion) have limited flow rates and as I_{time} is shortened tidal volume will fall quickly (I.e. - as RR is increased)
- THUS, just because your anesthesia machine has a pressure control setting... does not mean it can ventilate a critically ill patient



Nitric Oxide

- Inhaled NO can reduce PA pressures
- May improve oxygenation
- Only effective in acute pulmonary hypertension
- Approved for use in PPHN of newborn
- Risks: Methemoglobinemia
- Dose: 0 - 40 ppm (inhaled)
- Wean Slowly !!! (severe rebound pulmonary HTN can occur)

Management of the ARDS patient... other issues

- Volume Status: Aggressive reduction of intravascular volume status to reduce pulmonary edema
  - Thus...patients are less able to tolerate blood and volume loss
  - Be gentle with your fluids- or you may have acute worsening of hypoxia

Management of the ARDS patient... other issues

- Blood Transfusion Therapy: It is likely maximum hematocrit that is beneficial to these patients is 35%
- This is true only in most severely hypoxic patients...
- Average critically ill patient has been shown to have best survival when HGB is maintained between 7-9

Optimal Hemoglobin in the Critically Ill Patient !?!

? Clearly higher Hgb achieved via transfusion is not helpful and may be harmful

? Is there a lower threshold?

Transfusion Requirements in Critical Care

- Multicenter, RCT
- Subjects
  - Acutely ill in ICU, Hgb < 9.0
  - Excluded if: chronic anemia, ongoing bleeding, admission after CABG

Hebert et al. NEJM 1999; 340:409-17

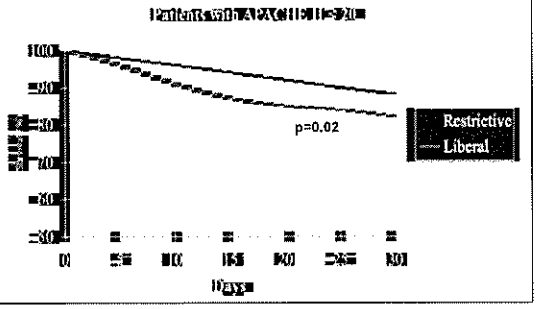
Transfusion Requirements in Critical Care

- Randomized to 2 strategies
- Liberal strategy:
  - Maintain Hgb between 10-12
- Restrictive strategy:
  - Maintain Hgb between 7-9
- Endpoints
  - All cause mortality, MSOF
  - Predefined subgroups: age > 55, CAD, APACHE II > 20

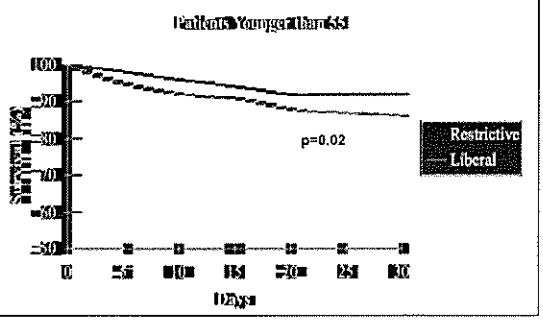
Transfusion Requirements in Critical Care

	Restrictive (n=418)	Liberal (n=420)	p
ICU mortality	8.4%	5.7%	0.29
Death (30d)	18.7%	23.9%	0.11
ICU LOS	11.0	11.5	0.53
MODS	8.3	8.8	0.10
MI	0.7%	2.9%	0.02

Transfusion Requirements in Critical Care



Transfusion Requirements in Critical Care



Transfusion Requirements in Critical Care

- Conclusions
  - - Lower transfusion threshold was as effective as higher trigger
  - - Lower threshold superior in some subgroups
  - - Mechanism of worse outcomes with liberal strategy unclear (? promotes cytokine cascade, increased risk of ARDS)

Transfusion Requirements in Neuro Critical Care

- Recent study (2006) in patients with moderate to severe head injury indicates no improvement in outcome with liberal (Hgb 10-12) versus conservative strategy (Hgb 7-9)

Neurocrit Care. 2006;5(1):4-9.

Transfusion Requirements in Critical Care (ABC study)

- ABC study reported in pts getting blood vs. no blood:
- Higher ICU Mortality (19 vs. 10%, $p < .001$)
- Higher overall mortality rates (29 vs. 15%, $p < .001$)
- In matched patients in a propensity analysis:
- 28-day mortality rate was 22.7% among patients with transfusions and 17.1% among those without ($p = .02$).

Vincent JL, et al. *JAMA* 2002; 288:1499-1507

Transfusion Requirements in Critical Care (Crit Study)

- CRIT study showed that the number of RBC transfusions a patient received during the study was independently associated with longer ICU and hospital lengths of stay and an increase in mortality.

Corwin HL, et al. *Crit Care Med* 2004; 32:39-52

Transfusion Requirements in Critical Care (SOAP)

- SOAP study:
  - evaluating 3,147 patients in 198 ICUs across Europe in May 2002,
  - Blood transfusion was not associated with increased mortality in multivariate analysis or by propensity case matching
  - Why ???

Vincent JL, et al. Abstr. *Chest* 2003; 124:125S

Transfusion Requirements in Critical Care (SOAP)

- SOAP study used leukoreduced blood
- May make a big difference in outcome
  - Many studies exist with some conflict in results.
  - Large European Multi-center study going on now

New Trends in Hemodynamic Management of the Critically Ill Patient in the OR

What may work....and what definitely does not !

Case Study

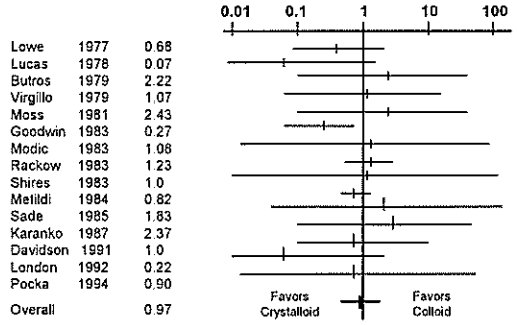
58 y.o. male with firm, distended abdomen and severe metabolic acidosis (lactate- 5.0) coming to OR for exploratory laparotomy

HR 110, BP 75/40, C.I. - 4.0 SVR- 458

Drips: vasopressin and fenaldopam

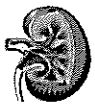
U/O - 5 cc last hour

Colloid vs Crystalloid Controversy



Choi PTL, et al. *Critical Care Med* 1999;27:200-10
Schierhout G, et al. *BMJ* 1998;316:961-4

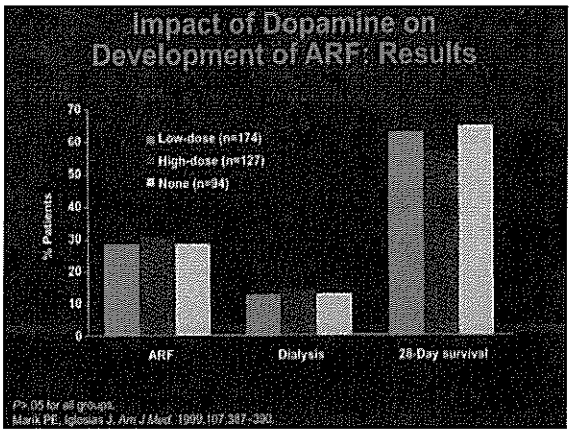
The urine output is dwindling...why not dopamine ??

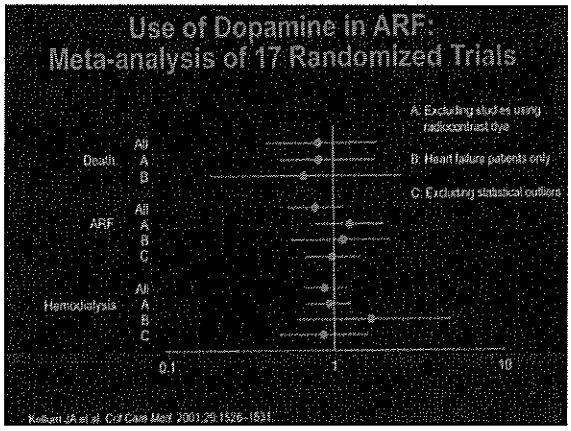


Dopamine for Renal Dysfunction

- RCT, 328 patients
- Included: 2 SIRS criteria *plus* oliguria *or* creatinine >1.7 *or* 24-hour rise in creatinine >0.9
- Dosing: Dopamine 2 µg/kg/min via CVC
- No differences found in
  - Peak creatinine, fraction with creatinine >3.4
  - Percent requiring renal replacement therapy
  - Time to recover renal function
  - Furosemide dose, ICU LOS, hospital LOS
  - Time on ventilator, survival

Bellomo R, et al. *Lancet* 2000;356:2139-43.



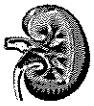


Dopamine

"Plasma dopamine clearance is lower in critically ill patients and there is a large interindividual variation. It is therefore impossible to predict the plasma level from the infusion rate. Consequently, the concept of a selective renovascular low-dose dopamine infusion is invalid in critically ill patients"

Intensive Care Med 1998 Nov;24(11):1217-20

So….is there anything I can do to try and preserve renal function in this patient ??



Maybe…

Fenaldopam

- DA-1 agonist
- Improves renal blood flow (low dose)
- Anti-hypertensive (high dose)
- Can reduce or eliminate need for nitroprusside

Dopamine Receptor Agonists

Actions of Dopaminergic Agonists

	Dopamine	Fenoldopam
DA_1 (vasodilation)	+++	+++
DA_2 (vasodilation, emesis inhibits prolactin)	+++	-
α (vasoconstriction)	++	-
β_1 (inotropic, chronotropic)	+++	-
β_2 (vasodilation)	+	-

+++ = Major action
++ = Moderate action
+ = Minimal action
- = No action

Frishman WH, Hotchkiss H. Am Heart J, 1996;132:861-867

Fenoldopam: Dosage and Administration

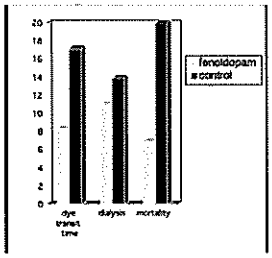
Dosing Recommendations

Usual starting dose = 0.1 µg/kg/min (0.03 - ? µg/kg/min)

- ✓ **Rapid titratable blood pressure control**
- ✓ **Minimal increase in heart rate**

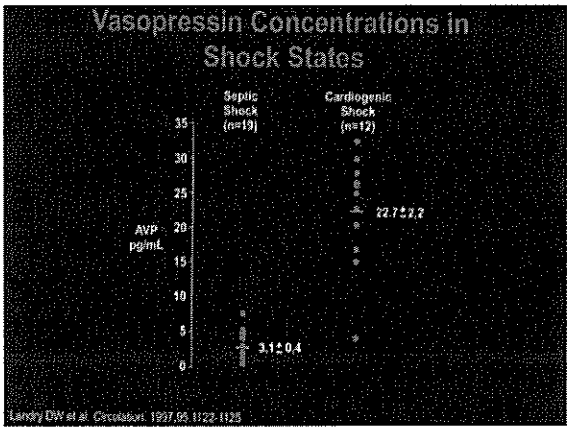
Fenoldopam in Thoracoabdominal Aneurysm Repair

Adapted from: Sheinbaum, R. Safi, H. et al. *Anesth Analg* 2000; 90: SCA 31

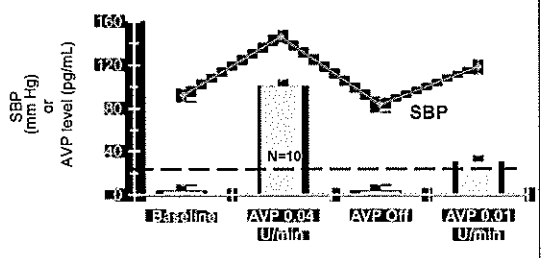


- **Design: Prospective, consecutive, case-series**
- **Fenoldopam group: N=58**
- **Non-fenoldopam group: N=30**
- **Treatment: Fenoldopam at 0.05 mcg/kg/min starting prior to and for 24 hours**
- **Baseline Characteristics: The fenoldopam group was significantly older (69.8 years vs. 64.1, p = 0.05) and had more renal risk factors (2.28 vs. 1.8, p = 0.05)**
- **Results: Fenoldopam use was associated with the following:**
  - **Increased renal blood flow**
  - **Reduced Dialysis**
  - **Reduced Mortality**
  - **Decrease ICU and hospital LOS**
  - **Decreased overall costs**

Vasopressin...Why Vasopressin ??



BP and Vasopressin Levels After AVP for Septic Shock



Landry DW, et al. *Circulation* 1997;95:1122-5
Landry DW, et al. *Crit Care Med* 1997;25:1279-82

Shock States: Dosing Vasopressin

Physiologic	Pharmacologic
• 0.01—0.04 U/min	• >0.04 U/min
• Plasma levels 20—30 pg/mL	• Plasma levels >100 pg/mL
• Synergistic activity with catecholamines	• Potential for renal, mesenteric, coronary, pulmonary vascular constriction
• No hypoperfusion	
• Some selective vasodilation	

Holmes CL et al. Chest 2001;120:989-1002

Vasopressin Summary

- VASS trial has just finished (Norepi versus Vasopressin in Septic Shock)
- Vasopressin was not better then norepinephrine in improving outcome from septic shock
- In severe sepsis, vasopressin led to increased digital necrosis versus norepi.
- Bottom Line: Levophed (Norepi) should be our first line therapy in sepsis for now

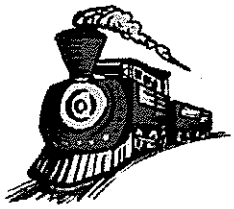
Conclusions

FIRE LINE - DO NOT CROSS FIRE LINE - DO NOT CROSS FIRE LINE - DO NOT CROSS

✳Suggested dose:

- ✳ Septic Shock: 0.04 U/min
- ✳ Post-CPB vasodilatation: 0.1 U/min

Electrolytes/Nutrition



Does any of this really matter in the trainwreck...YES !!

Treatment of Metabolic Acidosis (Should we treat at all ?)

- ✓Perhaps not...mild acidosis may be protective against reperfusion injury
- ✓However... if acidosis worsens... our pressors may stop working
- ✓In this patient who is already difficult to ventilate..$NaHCO^{3-}$ may worsen respiratory acidosis
- ✓So...if you need to treat... consider this...

Tromethamine (THAM)

- ✳ THAM - buffering agent that actually lowers CO_2 following administration
- ✳ Combines with H+ - renally excreted
- ✳ Has osmotic diuretic effect
- ✳ Very few studies done using this agent
- ✳ Again, renally excreted... so use with caution in renal failure
- ✳ Will cause tissue necrosis if it extravagates
- ✳ Dose: 500 cc bottle (frequent blood gases)

What About That Glucose of 250 ?

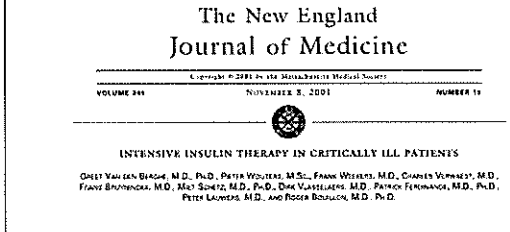
Who Cares...Right ??

WRONG !!!

Glucose Management

- ✓ Recent data indicates that keeping glucose < 110 can significantly improve outcome in critically ill
- ✓ Reduces infections, improves survival, shortens length of stay
- ✓ Often achieved via insulin drip protocol
- ✓ Intensive insulin therapy
  - ✓ Van den Berghe, NEJM 2001
  - ✓ 10.6% mortality versus 20.2% (NNT = 20)

Intensive Insulin Therapy in Critically Ill Patients


The New England
Journal of Medicine

INTENSIVE INSULIN THERAPY IN CRITICALLY ILL PATIENTS

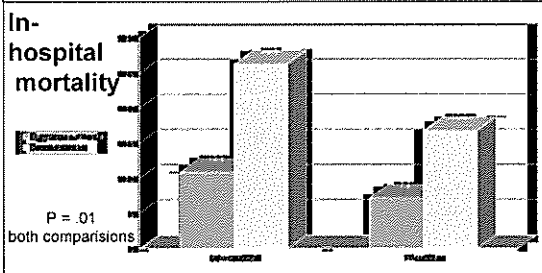
Van den Berghe G, et al N Eng J Med 2001;345:1359-1367

Intensive Glucose Control in the Critically ILL

- RCT, n = 1548
- Mechanically ventilated SICU patients
- Treatments
  - Titrate blood glucose 80-110
    - VS
  - Titrate blood glucose 180-200
- All patients received 200-300 gms glucose/d on day - 1 (?$D_{10}W$)
- TPN w/in 24 h of adm (60-80% as glucose cals)

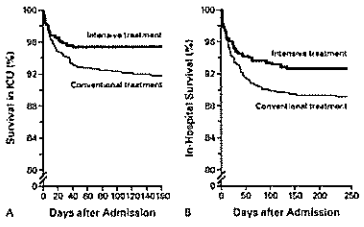
Berghe et al NEJM 345:1359 2001

Intensive Glucose Control Outcome



Berghe et al NEJM 345:1359 2001

Intensive Insulin Therapy in Critically Ill Patients: Kaplan-Meier Curves



Van den Berghe G, et al N Eng J Med 2001;345:1363

Intensive Insulin Therapy in Critically Ill Patients: Morbidity

- Percent of Patients with Renal Impairment

	Conventional n=783	Intensive n=765	P-value
Peak plasma creatinine >2.5 mg/dL	12.3%	9.0 %	0.04
Peak plasma urea nitrogen >54 mg/dL	11.2 %	7.7 %	0.02
Dialysis or CVVH	8.2 %	4.8 %	0.007

Van den Berghe G, et al. N Eng J Med 2001;345:1359-1367

Intensive Insulin Therapy in Critically Ill Patients: Morbidity

- Percent of Patients with Bloodstream Infections

	Conventional n=783	Intensive n=765	P-value
Septicemia during intensive care	7.8%	4.2%	0.003
Treatment with antibiotics > 10 days	17.1%	11.2%	<0.001

Van den Berghe G, et al. N Eng J Med 2001;345:1365

Glucose Management

- As a result... you are going to see a lot more insulin drips coming to OR
- It would be advisable to keep insulin drip running whenever possible (check frequent ABGs to prevent hypoglycemia)

Enhanced Perioperative Glucose Control in Diabetic Patients

- DESIGN: Prospective, sequential study
- POPULATION: Diabetic patients undergoing cardiac surgery (N=2467) during 1987-1997

  Controls: pts who received intermittent subQ insulin (SQI)

  Treated: pts who received continuous intravenous (IV) insulin

Furnary AP; Ann Thorac Surg, 2000

Enhanced Perioperative Glucose Control in Diabetic Patients

- OUTCOMES
  - Blood glucose <200 mg/dl in first two days postop
  - Incidence of deep sternal SSI
- RESULTS
  - SQI group: 2.0% (19/968) vs
  - IVI group: 0.8% (12/1499), p=0.01

Furnary AP; Ann Thorac Surg, 2000

Supplemental Perioperative O_2

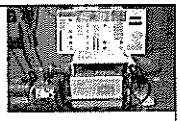
- DESIGN: Randomized controlled trial, double blind
- POPULATION: Colorectal surgery (N=500)
- INTERVENTION: 30% vs 80% inspired oxygen during and up to hours after surgery
- RESULTS: SSI incidence 5.2% (80% O_2) vs 11.2% (30% O_2), p=0.01

Greif, R, et al , NEJM, 2000

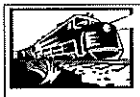


Clinical Pearls to Get the Train Back on Track

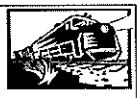
Transport



- BRING ICU VENTILATOR- (if you do not have one of the new advanced anesthesia ventilators)
- <u>If patient is on ICU vent- transport on ICU vent- many have batteries !</u>
- Get respiratory therapist to assist



Transport



- If you have to hand ventilate patient and they are on > 5 of peep...make sure to use AMBU bag with PEEP valve
- Remember for all ICU patients- loss of PEEP causes lung derecruitment- and can cause a quick end to your case due to hypoxia !!!
- Paralyze every intubated, critically ill patient prior to transport

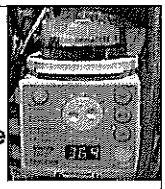
Transport

- Take as few pumps as you can-- how many of you have seen those towers of pumps tip over and pull out all your lines
- TPN... you do not have to take it... if on an insulin drip... I would
- But... again frequent ABG's to avoid hypoglycemia
- Cover patient prior to transport... a cold patient is a bleeding patient and one that is more likely to become infected post-op (remember that from boards ??)

Intaoperative Management

- FREQUENT ABG'S !!!!!!!!!!!!!!!!!!!!
- At least every 30 - 45 min in the sickest of patients
- You have to know what is going on... NEVER BE SURPRISED BY THAT CO2 of 70...BASE DEFECIET OF -10... OR HCT OF 18.
- If you prevent shock and acidosis the case continues and you can keep very sick patients in OR a long time
- In theory...patient should look better after they leave OR then when they arrived
- When else will they get one on one care from a master physiologist and pharmacologist like yourself...use OR as a chance to optimize the patient

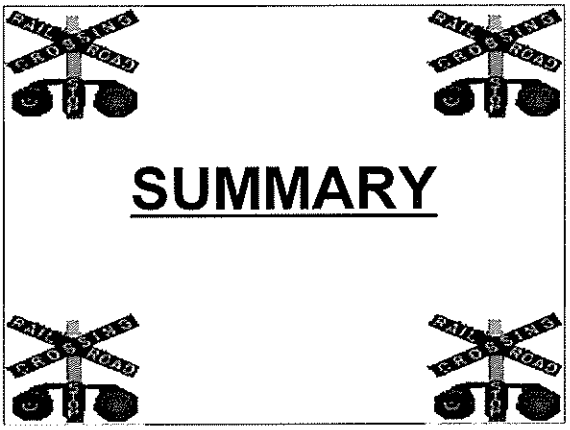
Intraoperative Management



- If on ICU ventilator...many have humidifier/warmers
- These devices can heat inspired gas to 40 deg. C and core warm your patient
- They also actively humidify airway gas and decrease impacted secretions

Intaoperative Management: Common sense Issues

- A-lines are mandatory for any big trainwreck- if it falls out, put it back before they cut !
- CVP can be very helpful
- ALWAYS, have good access- a cortis is often mandatory
- ICU patients are notorious for having lines fall out on transport- Guard them with your life- replacement is not always easy
- Follow urine output closely
- AGAIN, frequent blood gases !!



Summary: Ventilation of the Trainwreck

- Anesthesia machines can not ventilate many critically Ill patients with severe lung injury
- If patient is on ICU ventilator... consider taking ICU ventilator to OR
- Pressure Control can be a very useful mode of ventilation... as long as close monitoring of tidal volume is maintained

Summary: Hemodynamic Support

- Vasopressin is a very useful in vasodilated shock...
- But... keep your doses low (0.04 - 0.1 units/min) and minimize titration
- Dopamine DOES NOT prevent renal failure or have any benefit on preservation of renal function
- Fenaldopam may preserve renal function in some patients

Summary: Clinical Pearls

- Transport can be fraught with peril...
  - Paralyze patient
  - Transport on own ventilator if possible
  - If on peep > 5... use ambu with peep
- Intraoperative Management
  - Frequent ABGs !
  - Keep Warm !
  - Suction Often !

Critical Care Review:What the Anesthesiologist Needs to Know

Paul Wischmeyer M.D.
Associate Professor of Anesthesiology
University of Colorado Health Sciences Center

Case Study

☹ It's now 3 pm and you get the dreaded call there is an emergency case for an exploratory lap that needs to go now !