F.I.R.E Up Your Rapid Response Team: Non-Invasive Technologies and the Next Era of Rapid Response

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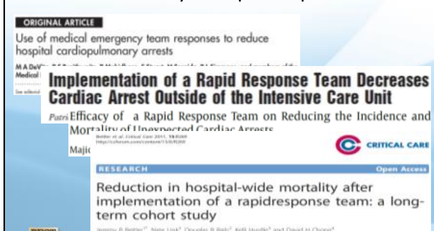
The History of Rapid Response

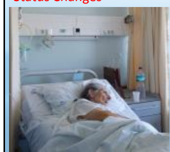


Introduction and Evolution of Rapid Response Team (RRT)

- An additional trigger
- Non-invasive tools for determining higher level of care
- What patient populations do we serve?
- RRT's evolution and the next step in patient care
- Nurse Driven

Case Study 65 y.o. female

RRT Reason for Call: Hypotension, Mental Status Changes



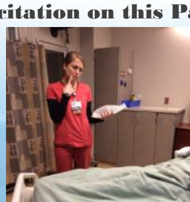
Past Medical History:

- ESRD-HD Dependent
- Hypertension
- Personal history of stroke
- CAD
- Myocardial infarction
- Thyroid disease
- Anemia
- Hemodialysis dependence
- Unspecified disorders of the nervous system
- History of atrial and ventricular arrhythmias
- Left ventricular hypertrophy
- SVC obstruction
- Embolism and thrombosis of unspecified artery

Case Study: 65yo Female

- RRT Arrives to the bedside
- What did we know:
  - 65 y/o female w/ PMH of renal cell carcinoma s/p L radical nephrectomy in 2/14, hyperparathyroidism, hypercalcemia, CAD, MI, HTN and stroke presents w/ AV fistula thrombosis after IR declotting on 11/25.
  - Recent dialysis the day prior for 2 hours and stopped d/t hypotension with a Hgb 6.1 gm/dl
  - Lactic Acid 12mmol/L
  - VS: BP 87/40, HR 88, RR 16, Temp. 36.5 C, 98% on RA

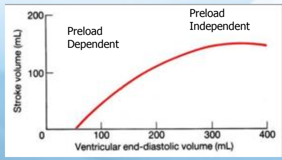
Would You Initiate Fluid Resuscitation on this Patient?



Fluid Resuscitation-What We Know

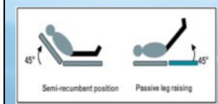
- About half of hemodynamically unstable critically ill patients will respond to fluid (Marik, 2013; Michard & Teboul. 2002)
- Volume overload in the critically ill patient is associated with increased length of stay and mortality (Boyd, 2011; Shum, 2011)
- Early fluid resuscitation is associated with improved outcomes, while late fluid resuscitation is associated with increased morbidity and mortality (Murphy, 2009; Warndorff, 2011; Westphal, 2013; Rivers, 2001)
- Clinical Indicators of hypovolemia are often inaccurate, confounding, or late signs (Fortes, 2014)

Frank-Starling's Law



Functional Hemodynamics

Functional Hemodynamic measures analyze the patient's *response* to an intervention. A reversible fluid challenge (ie PLR) or 300-500ml IVF bolus is given and response is assessed over the next 5-10 minutes. **An increase of SV, CO,RVEDVI, or FTc of 10% or more indicates fluid responsiveness.**



Passive Leg Raising

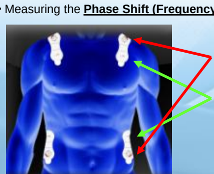
- Involves the reversible autotransfusion of the blood from the dependent lower extremity vessels to the vena cava to assess for improvement in stroke volume/cardiac output
- Extremely well validated in the literature with an average sensitivity and specificity of 80-85% (Boulain, 2002; Monnet, 2006; Lafarenchere, 2006; Lamia, 2007; Maizel, 2007; Caille, 2007)
- Requires some measure of continuous cardiac output or stroke volume, or dynamic indices, in most cases

Non-invasive Bio-Reactance

- Measures the frequency of electrical signals in the thorax
- Changes in aortic blood flow alters electrical signals
- Data for fluid responsiveness is excellent (Dunham 2012, Raval 2008, Benomar 2010, Fagnoul 2012, Marik 2013)
- More studies are needed for pressors/myocardial depression states

HOW DOES BIO-REACTANCE WORK?

- Ventricular outflow drives changes in Phase (Phase Shift) of radiofrequency waves as they cross the chest
- Measuring the **Phase Shift (Frequency)** enables exact calculation of flow



An electric current of known frequency is applied across the thorax between the outer pair of sensors

A signal is recorded between the inner pairs of sensors

Change in phase of the frequency is recorded and the signal translated to flow (similar to Doppler concept)

Now Back To Our Case Study

Case Study: 65yo female with complicated history

Bioreactance results: 250ml bolus

Fluid Bolus Challenge: No, Passive Leg Raise: Yes Time started: 1133

	CO	CI	HR	NIBP	MAP	TPR	TPRI	SV	SVI	SVV
Baseline		2.2	87		53		1939		25	
Challenge		2.3	86		59		2069		27	

Stroke Volume Index Change: **3.9%**

Diagnosis: Septic Shock

- Complicated with ESRD and history of stent placement and MI
- Started on CRRT and eventually levophed. No additional fluids given.
- Repeat bioreactance numbers also determined non-fluid responsiveness when admitted to ICU.

Non-Invasive Hemodynamics and RRT at The University of Kansas Hospital

Fluid Resuscitation in Symptomatic Hypotension:

- Obtain baseline hemodynamic values from noninvasive bioreactance monitor, if available.
- Administer 500 mL of IV NS or LR over 5 to 10 minutes, and evaluate change in stroke volume index (SVI) (≥10% increase indicates fluid responsiveness).
- If patient tolerance of fluid bolus is of concern, consider passive leg raise (PLR) test to assess fluid responsiveness prior to administering bolus.
- Repeat bolus X 3 if patient remains fluid responsive. Refer to Assessment of Fluid-Responsiveness-TUKH Procedure.
- If bioreactance monitor not available, administer fluid boluses as above and monitor for improvement in blood pressure.

Implementation

- Nursing and Physician Education
  - Technical aspects
  - Principles of fluid responsiveness
  - Inaccuracy of clinical findings
- How to address FR diagnosis when fluid resuscitation has already begun
- At risk populations

Case Study 2: 62 yo female

- 62 y.o. female with PMH of metastatic mucinous adenocarcinoma of appendix, s/p multiple abdominal surgeries, complicated by abscesses, resecting of colostomy
- RRT trigger: Hypotension
- 6L NS given prior to arrival
- Substantial amount of output via colostomy

Case Study 2: 62 yo female

	CO	CI	HR	NIBP	MAP	TPR	TPRI	SV	SVI	SVV
Baseline		3.7	88	79/44					42	
Challenge		4.2	97	83/45					50	

Stroke Volume Index Change:19 **%**

Case Study 2: 62 yo female

Subsequent readings

- 1610: Passive leg raise completed after 2nd 1000 mL bolus of NS (1st and 2nd 1000 ml bolus initiated during rapid response). SVI change of 12.3%. Orders for 3rd 1000 mL bolus.
- 1900: PLR completed again with SVI change of 11%. Orders for an additional 1000 ml NS.
- Prior to 1900 an SVI of 2.4% obtained?

24 hour Intake and Output

Intake	9072.31 ml
Output	6650 ml
Net	2422.31 ml

RRT and Bioreactance Conclusions

- Allows for evidence-based fluid resuscitation practices, even on the floor
- Assists with a quicker determination of need to transfer to higher level of care
- AKIKO-We need hypotension data here.

CAPNOGRAPHY MONITORING AND RAPID RESPONSE

Case Study 4: 35yo male

- Admitted for Anterior Posterior L4-S1 fusion
- Fentanyl PCA for pain initially, switched to morphine PCA after reports of poor pain control
- Assessment findings:

Arrival to the floor 0930		1130-PCA Switched		1230-Follow Up	
HR	90 bpm	HR	72 bpm	HR	74 bpm
RR	28/min	RR	24/min	RR	18/min
SpO2	98% on 2L	SpO2	98% on 2L	SpO2	98% on 2L
POSS score	2-Slightly drowsy, easily aroused	POSS score	2-Slightly drowsy, easily aroused	POSS score	Sleeping
BP	95/60	BP	90/58	BP	92/60
Pain Score	8	Pain Score	4	Pain Score	Sleeping

Case Study 4: 35yo male

- RRT called at 1300 after pt found unresponsive by Nurse's Aid
- Pt being assisted with ventilation via BVM upon RRT arrival
- Some response to naloxone .04mg x3 doses
- Intubated by anesthesia and transferred to the Surgical ICU

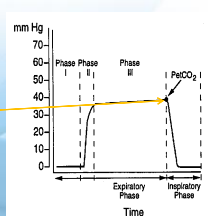
Principles of Capnography Monitoring

- Capnography monitors the amount of carbon dioxide being expelled throughout the respiratory cycle and produces a waveform that provides additional information about the patient's respiratory, CV and metabolic status

Principles of Capnography Monitoring

Phase I-Baseline period of no CO2; end of inhalation
Phase II-Rapid rise in CO2
Phase III-Alveolar plateau
Phase IV-Inhalation

EtCO2 obtained at the peak of Phase III. Provides the highest expired CO2 value during the respiratory cycle
NORMAL EtCO2 is 35-45mmHg



Why ETCO2?-- I Have my Pulse Ox

Pulse Oximetry	Capnography
Oxygen Saturation	Carbon Dioxide
Reflects Oxygenation	Reflects Ventilation
SpO2 changes lag when patient is hypoventilating or apneic. Supplemental oxygen can obscure SpO2 readings	Hypoventilation/Apnea detected immediately

Risk Factors for Opioid-Induced Respiratory Depression

- High-risk populations
  - Obese
  - Obstructive sleep apnea and/or chronic pulmonary disease
  - Increasing age
  - Impaired renal/hepatic function
  - Multiple comorbidities
  - Neurologic disorders, eg. multiple sclerosis, Guillain-Barre
  - PCA
  - Continuous opioid infusions
  - Receiving multiple opioids or concurrent sedating medications

Capnography at The University of Kansas Hospital

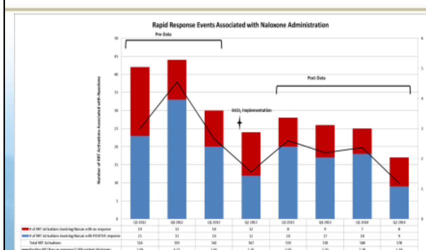
- 4 patient populations
  - All patients receiving patient controlled analgesia
  - All patients receiving procedural sedation (ASA ref)
  - All patients undergoing cardiopulmonary resuscitation
  - All patients receiving mechanical ventilation
- Nurses and physicians may initiate EtCO2 monitoring in any other at risk patients as requested
- Portable EtCO2 monitors are carried by the rapid response team and respiratory therapists

Case Study 4: 65 yo female

- S/P R Total Knee Replacement
- PMH
  - Chronic pain requiring long term opioids and adjuncts
  - Hypertension
  - Obesity
- Fentanyl PCA and gabapentin ordered in addition to home medications for postoperative pain management

Case Study 4: 65 yo female

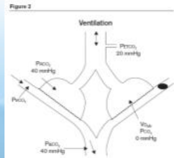
Arrival to the floor 1345		1500		1525	
HR	105 bpm	HR	93 bpm	HR	97 bpm
awRR	26/min	awRR	20/min	awRR	6/min*
SpO2	94% on 2L	SpO2	93% on 2L	SpO2	94% on 2L
POSS score	2-Slightly drowsy, easily aroused	POSS score	2-Slightly drowsy, easily aroused	POSS score	3-Frequently drowsy, arousable, drifts off to sleep during conversation
BP	128/86	BP	126/80	BP	128/78
Pain Score	8	Pain Score	5	Pain Score	Not taken
EtCO2	20mmHg	EtCO2	40mmHg	EtCO2	55mmHg*
Nursing Actions	Home PO meds given	Nursing Actions	PCA bolus given	Nursing Actions	MD notified, dose ↓



Other Uses for Capnography in Rapid Response

Deadspace ventilation resulting in a widened PaCO2-EtCO2 gradient

Figure 2



Anderson & Breen, 2004

Utilization of the PaCO2-EtCO2 Gradient in Practice

- As an indicator of alveolar dead space
  - PaCO2-EtCO2 gradient is an unbiased and precise indicator of Vd/Vt (Frankenfeld et al, CCM, 2010)
  - Numerous papers describe the use of the PaCO2-EtCO2 gradient in the early recognition and diagnosis of **acute pulmonary embolism** (Park 2013, Thys 2001, Wiegand 2000, Verschuren 2004)

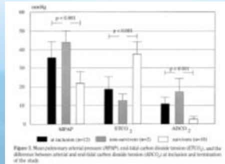
Table 4 Comparison of our study results on capnography for PE with other reports from the literature

	Test	Sn (%)	Sp (%)	PPV (%)	NPV (%)
Kar Kurt et al	AVDSf (0.09)	70	61.1	80	47.8
	AVDSf + Wells scores	80	61.1	82.1	57.9
	AVDSf + D-dimer	89.7	27.8	72.9	55.6
	AVDSf + VDUSG	82.5	55.6	80.5	58.8
	V/Q + AVDSf	82.5	52.9	80.5	56.2
Kline et al [8]	AVDSf (0.20)	67.2	76.3		
	D-dimer	93.8	67.1		
	D-dimer + AVDSf	98.4	51.6		
Rodger et al [9]	AVDSf (0.15)	79.5	70.3		
	D-dimer	83	57.6		
Hogg et al [10]	AVDSf (0.32)	93.3	20	6.2	98.7
Sanchez et al [11]	AVDSf (0.15)	68.5	81.5	71.1	79.5
	AVDSf + Wicki scores	70	61.1	80	47.8

Kar Kurt et al, Am J Em Med, 2010

Utilization of the $PaCO_2$-$EtCO_2$ Gradient in Practice

-Monitoring response to thrombolytic therapy in PE



Wiegand et al. CCM; 2000:28(11)

Assessment of fluid responsiveness in hemodynamic instability

Table 1. End-Tidal and Volumetric CO_2 Elimination in the "Fluid" Responders and Nonresponders

	Responders ($n = 24$)	Nonresponders ($n = 20$)	p Value
Initial SVI (mL/min/m²)	29.1 ± 8.6	31.4 ± 8.2	0.36
Delta $PETCO_2$ (mmHg)	1.8 ± 2.2	0.5 ± 1.8	0.03
% change $PETCO_2$	5.9 ± 7.6	1.4 ± 4.4	0.02
PLR ($n = 10$)	6.2 ± 1.4	2.4 ± 3.6	0.13
Fluid bolus ($n = 34$)	5.9 ± 8.2	0.8 ± 4.8	0.05
Non-COPD ($n = 31$)	8.1 ± 8.1	1.9 ± 4.5	0.01
COPD ($n = 13$)	2.2 ± 5.2	0.5 ± 4.2	0.37
Delta VCO_2 (mL/min)	19.9 ± 16.7	1.5 ± 9.9	<0.001
% change VCO_2	11.0 ± 8.6	0.8 ± 5.6	<0.001
PLR	11.9 ± 8.1	3.0 ± 5.9	0.08
Fluid bolus	10.9 ± 8.9	0.4 ± 5.3	<0.001
Non-COPD	14.7 ± 7.8	1.1 ± 5.8	<0.001
COPD	5.2 ± 6.6	0.3 ± 4.9	0.18
SVV (%)	15.8 ± 3.7	13.6 ± 4.8	0.15

Table 2. Area Under the ROC Curve (With 95% Confidence Intervals) for End-Tidal and Volumetric CO_2 Stratified by the Presence or Absence of COPD

	All Patients ($N = 44$)	No COPD ($n = 31$)	COPD ($n = 13$)
$PETCO_2$	0.67 (0.48-0.80)	0.74 (0.52-0.87)	0.60 (0.19-0.83)
VCO_2	0.79 (0.63-0.89)	0.87 (0.68-0.95)	0.71 (0.34-0.89)

Young et al Cardiothoracic and Vasc Anes. 2012

$EtCO_2$ as an indicator of airway obstruction/bronchoconstriction

- Indicated by an increasing slope of Phase III, AKA the "shark fin" waveform

- Several case reports in the literature of this being the earliest clinical sign of obstruction (Busaidy 2011, Stromberg 2000, Krauss 2005, Thompson 2005, Yaron 1996, You 1994, Kars 1997)

Capnography Conclusions

- Capnography monitoring in high risk patients receiving opioids has reduced our incidence of rapid response calls associated with respiratory depression
- Several pulmonary embolisms have been diagnosed with the use of EtCO2
- We need a better system to triage high risk patients for use of EtCO2

Other Non-Invasive Technologies

- Obstructive Sleep Apnea Patients
  - Respiratory Acoustic Monitoring (RAM)
  - Capnography monitoring with positive airway pressure
- Non-Invasive Hemoglobin Monitoring
- Pleth Variability Index
- Volume Clamp Stroke Volume Monitor
- Tissue oxygenation sensors

Conclusion

- The next era of Rapid Response will focus on prevention of complications!
- Further studies investigating the outcome of non-invasive technologies are needed
- Attack one population at a time for biggest impact.

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