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

Implementation of a Rapid Response Team Decreases Cardiac Arrest Outside of the Intensive Care Unit

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
• Hypertension
• Personal history of stroke
• CAD
• Myocardial Infarction
• Thyroid disease
• Anemia
• History of atrial and ventricular arrhythmias
• Left ventricular hypertrophy
• SVC obstruction
• Embolism and thrombosis of unspecified artery

RRT Reason for Call:
Hypotension, Mental Status

Would You Initiate Fluid Resuscitation on this Patient?

RRT Arrives to the bedside

What did we know:
– 65 y/o female w/ PMH of renal cell carcinoma s/p L renal
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
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 (Michard, 2002; Teboul, 2002).
- 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

Preload Dependent

Preload Independent

Functional Hemodynamics

Functional Hemodynamic measures analyze the patient's response to an intervention. A reversible fluid challenge (e.g., PLR) or 330-500ml 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 pair of sensors
• Change in phase of the frequency is recorded and the signal translated to flow (similar to Doppler concept)
Case Study: 65yo female with complicated history

Bioreactance results: 250ml bolus
Fluid Bolus Challenge: No, Passive Leg Raise: Yes Time started: 1133

<table>
<thead>
<tr>
<th></th>
<th>CO</th>
<th>CI</th>
<th>HR</th>
<th>NIBP</th>
<th>MAP</th>
<th>TPR</th>
<th>TPRI</th>
<th>SV</th>
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<td>87</td>
<td>53</td>
<td>1939</td>
<td>25</td>
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<tr>
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<td>86</td>
<td>59</td>
<td>2069</td>
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Stroke Volume Index Change: 3.9%

Diagnosis: SepticShock

- 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 a concern, consider passive leg raise (PLR) test to assess fluid responsiveness prior to administering initial 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
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?

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**24 hour Intake and Output**

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<td><strong>Intake</strong></td>
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<tr>
<td><strong>Output</strong></td>
<td>6650</td>
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<tr>
<td><strong>Net</strong></td>
<td>2422.31</td>
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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.

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CAPNOGRAPHY MONITORING AND RAPID RESPONSE

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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

<table>
<thead>
<tr>
<th>Assessment Time</th>
<th>HR (bpm)</th>
<th>RR (breaths/min)</th>
<th>SpO2 (%)</th>
<th>POSS Score</th>
<th>Pain Score</th>
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<td>1230</td>
<td>74</td>
<td>18</td>
<td>98</td>
<td>Sleeping</td>
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</table>

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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, 0.04mg 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.

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**
  - Oxygen Saturation
  - Reflects Oxygenation
  - SpO2 changes lag when patient is hypoventilating or apneic. Supplemental oxygen can obscure SpO2 readings

- **Capnography**
  - Carbon Dioxide
  - Reflects Ventilation
  - Hypoventilation/Apnea detected immediately

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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

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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

<table>
<thead>
<tr>
<th>Time</th>
<th>Arrived</th>
<th>HR</th>
<th>RR</th>
<th>SpO2</th>
<th>POSS</th>
<th>BP</th>
<th>Pain</th>
<th>Nursing Actions</th>
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<tr>
<td>1345</td>
<td></td>
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<td>105</td>
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<td>1500</td>
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<td>94%</td>
<td>3</td>
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<td>97</td>
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Nursing Actions
- PCA bolus given
Other Uses for Capnography in Rapid Response

Deadspace ventilation resulting in a widened PaCO2-EtCO2 gradient

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

Kar Kurt et al, Am J Em Med, 2010
**Utilization of the PaCO2-EtCO2 Gradient in Practice**

- Monitoring response to thrombolytic therapy in PE

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

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**Assessment of fluid responsiveness in hemodynamic instability**

Young et al Cardiothoracic and Vasc Anes. 2012

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**EtCO2 as an indicator of airway obstruction/bronchoconstriction**

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

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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References


References

- ASA Standards for Basic Anesthetic Monitoring, Committee of Origin: Standards and Practice Parameters (Approved by the ASA House of Delegates on October 21, 1986, and last amended on October 20, 2010 with an effective date on July 1, 2011)
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