How to start multimodality monitoring in your ICU

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Disclosures

- No financial disclosures
Objectives

- Big picture rationale for multimodality monitoring
- Understanding that there are really 3 problems plus 1, with no perfect solution
- Data connectivity basics and a little more.
- Commercial help is likely in order.
Why Multimodal Monitoring?

- CBF
- pbO₂, pbCO₂, pH, brain temp
- Microdialysis
- SjvO₂
- ICP/CPP
- cEEG
- TCD
Traditional Cardiopulmonary Monitoring

Fuel
- $P_aO_2$
- Glucose

Delivery System
- HR
- Cardiac Index
- Volume Status
- CPP = MAP - ICP
Did fuel arrive and was it enough?
Good-grade patient: Steer by exam
Poor-grade patient: Steer by gauges
Rationale for multimodal monitoring

- Did the fuel arrive?
  - CBF monitoring
  - LICOX ($P_bO_2$)
  - CMA (brain glucose)

- Was it enough fuel?
  - CMA (Lactate / Pyruvate ratio changes)

- Are there demand / metabolism changes?
  - $P_bO_2$ and brain glucose changes in accordance to lactate and pyruvate moving up or down together

- Is the neuronal activity healthy?
  - EEG / qEEG
Go in with your wide eyes open

- Requires effort
- Need at least a physician and nursing champion.
- A LOT goes on unnoticed – think EEG part II.
- Switching mentality from action / no action to understanding physiology
- Requires more thinking, not less.
- You might question current practices.
So you really want to get wired

Three Problems + 1
- Data Collection
- Data Interrogation
- Data Analysis
- Best use of data for clinical decision making
Data Collection
Data Sources

- Physiologic Monitor
  - Heart Rate
  - Blood Pressure
  - ICP
  - PbtO2
- Ventilators
- Infusion Pumps
- Stray devices
  - Cooling devices
  - Microdialysis
- Labs
  - Systemic Glucose
  - Sodium
  - Hemoglobin
- Clinical Exam
- Oral Medications
- Patient Events
- Patient Plan Goals
Strategic Considerations

**Strategic**
- Data types (parameter / waveform / lab / clinical)
- Scope (clinical / research)
- Scale (1 bed / 40 beds)
- Electronic versus manual data entry
- Institutional investment
- Political leverage

**Who ‘controls’ the data?**
- Clinical Staff
- Hospital Administration
- Core Labs
- Biomedical Department
- IT Departments

Be open to creative solutions
ICP SUREKHA PATEL

**Mannitol 20%**

**3% Saline**

**Osmolal Serum**

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**Graph:**

- **ICP**
- **Mannitol 20%**
- **3% Saline**
- **Osmolal Serum**

**Y-axis:** mmHg

**X-axis:** Time (08:00, 16:00, 00:00)

**Legend:**
- Black line: ICP
- Blue line: Mannitol 20%
- Red line: 3% Saline
- Green line: Osmolal Serum
Getting yourself started

Do-it-yourself

1

2

3

4

5

6

*Cardboard backing not included
The Connectivity Lingo
Connectivity: The Basics

- RJ-45 (Cat 5 Cable): Standard Ethernet Cable
- If Building a new unit get as many jacks in each room as possible (>10).
Connectivity: The Basics

- DB9 (RS232 / RS485) 9-pin connector
  - RS232 allows one connection to device
  - RS485 allows multiple connections to device
Connecting a Device to a Computer

Why can't I hear you?!
RS-232 Null Modem Adapter/Cable

- Allows two devices to talk back and forth with each other.
CAT-5 Crossover Cable

- Allows two devices to talk back and forth with each other.
Connection Adapters

For example: DB9 to RJ-45 adapter
Communications Port (COM)
Creating a Device Interface

Example: 13, 36.5, 36.4, 34.5, 2, 0, 14.3, 14.4, 16.5, 4.6, 14.2, 0, 60, 0, 2, 3, 5, -7.1, 0, 45, 165, 1, 0, 0

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<td>Sequence Start Indicator</td>
<td>$ (ASCII 36)</td>
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<tr>
<td>2</td>
<td>Serial Sequence Number</td>
<td>1, 2, 3, 4, 5 ... , Initialized at power up</td>
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<tr>
<td>3</td>
<td>Patient Temperature 1</td>
<td>(C, 0 if probe not connected)</td>
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<tr>
<td>4</td>
<td>Patient Temperature 2</td>
<td>(C, 0 if probe not connected)</td>
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<tr>
<td>5</td>
<td>Patient Target Temperature in Auto Mode</td>
<td>(C, Regardless of current mode)</td>
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<tr>
<td>6</td>
<td>Operating Mode</td>
<td>0 = Initialization, 1 = Stop, 2 = Automatic, 3 = Manual, 4 = Purge, 5 = Fill</td>
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<tr>
<td>7</td>
<td>Diagnostic Mode</td>
<td>0 = Normal Mode, 1 = Diagnostic Mode</td>
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<tr>
<td>8</td>
<td>Outlet Water Temperature Monitor</td>
<td>ºC</td>
</tr>
<tr>
<td>9</td>
<td>Outlet Water Temperature</td>
<td>ºC</td>
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<tr>
<td>10</td>
<td>Inlet Water Temperature</td>
<td>ºC</td>
</tr>
<tr>
<td>11</td>
<td>Chiller Temperature</td>
<td>ºC</td>
</tr>
<tr>
<td>12</td>
<td>Water Outlet Target Temperature</td>
<td>ºC</td>
</tr>
<tr>
<td>13</td>
<td>Temperature Display Mode</td>
<td>0 = ºC, 1 = ºF</td>
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<tr>
<td>14</td>
<td>Communications Output Interval</td>
<td>Seconds</td>
</tr>
<tr>
<td>15</td>
<td>Current Alarm Number</td>
<td>See Alarm/Alert list for corresponding numbers</td>
</tr>
<tr>
<td>16</td>
<td>Flow Rate</td>
<td>Liters/minute</td>
</tr>
<tr>
<td>17</td>
<td>Reservoir Level Last Measured</td>
<td>5 or 4 = Full, 3 = 3/4, 2 = 1/2, 1 = Low, 0 = Empty</td>
</tr>
<tr>
<td>18</td>
<td>Inlet Pressure</td>
<td>Pounds per square inch</td>
</tr>
<tr>
<td>19</td>
<td>Heater Power</td>
<td>0-32 where 32 = 100%</td>
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<tr>
<td>20</td>
<td>Mixing Pump Power</td>
<td>0-255 where 255 = 100%</td>
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<td>21</td>
<td>Flow Pump Power</td>
<td>0-255 where 255 = 100%</td>
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<td>22</td>
<td>Control Parameter Mode</td>
<td>0 = Surgical, 1 = ICU</td>
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<tr>
<td>23</td>
<td>Reserved Data</td>
<td></td>
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<tr>
<td>24</td>
<td>Reserved Data</td>
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Example: Arctic Sun data over Intranet to a server
Pulling It All Together
Monitor Specific Solutions

- CMA ICU Pilot allows one to interrogate the relationships in the data
- Integra Mobius allows archiving of waveform data
Unit Wide Data Collection

- Excel Medical (Bedmaster)
- Parameter data at 5 seconds
- Saves All visible waveforms
- SQL database (open and extensible)
- Supports GE monitors now, Philips in near future
- 18 bed unit requires ~500 GB a year in storage (not including EEG)
Getting Other Data Electronically

- Relevant Data: Labs, Medications, Clinical Exam Scores, etc.

- Key Concepts:
  - Electronic Medical Record
  - Interface engines
  - Computable Semantic Interoperability
    - ADT messages
    - HL7

- Tension between data availability and security and data integrity concerns.
**Mission: Go to Gap, Buy a Pair of Pants**

**THE MALE BRAIN**
- BALL SPORTS
- DANGEROUS PURSUITS
- SEX
- SEX
- DANCE
- SHOE MAJORING
- AUDITING
- domestic skills
- crutch scanning area
- toilet aiming cell
- t.v. and remote control addiction centre

**THE FEMALE BRAIN**
- INDECISION NUCLEAS
- TELEPHONE SKILLS
- CHOCOLATE CENTRE
- NEED FOR COMMITMENT HEMISPHERE
- SENSE OF DIRECTION NEURON
- SEX (see note)
- LISTENING
- SHOPPING

**FOOTNOTE:** The "Listening to children cry in the middle of the night" gland is not shown due to its small and underdeveloped nature. Best viewed under a microscope.

**FOOTNOTE:** Note how closely connected the small sex cell is to the listening gland.
Rules/Regulations related to Security

- **JCAHO:** Joint Commission on Accreditation of Healthcare Organization – *Information Management*
- **HIPAA:** Health Insurance Portability and Accountability Act – *Information Security of Electronic Protected Health Information*
- **Sarbanes-Oxley Act of 2002** – *Audit functions for financial data*
- **Common Rule (45 CFR Part 46)** – *Protection of Human Subjects (Institutional Review Board, GCP)*
- **21 CFR Part 11** – (FDA) *Data Security, Electronic signatures, etc.*
- **CDC/NIH/FDA** Biological Safety Labs and Bioterrorism, information security
- **FERPA:** Family Educational Rights and Privacy Act – *Medical/Nursing/Dental students’ data*
- **State Laws** on HIV and Mental Health Information
- **State Information Security Breach and Notification Act**
- **State Social Security Number Protection Act**
- **Payment Card Industry** Data Security Standard
- **DMCA:** Digital Millennium Copyright Act of 1998 – *Copyright violations among immature users*
Computable Semantic Interoperability

- Ability for two or more systems exchange information and to use the exchanged information correctly.

- **Syntax vs. semantics.**
  - Syntax is structure
    - “The dog eats red meat”
    - “The dog sings blue trees”
  - Semantics is meaning
    - “The patient was given pain medication”
    - “The patient was given medication for pain”
The Need for Standards

- Terminology Servers (Medical, Lab)
- Master Patient Indices
- Systems transmit information in different formats from each other – need for interface engine
Interface Engines

Formats: HL7, DICOM
Protocols
Asynchronous/Batch: FTP, Email, scp
Synchronous: Sockets over TCP/IP, Web Services
Synchronous: Services
Content management
Conversion Tables (MED)
Routing and Message transformation
Failure Handling
<!-- Example payload for Emergency Encounter Started (PRPA_MT403001) -->
<encounterEvent className="ENC" moodCode="EVN">
  <id root="2.16.840.1.113883.19.3.2409" extension="12345" displayable="true" />
  <code code="EMER" codeSystem="2.16.840.1.113883.5.4" codeSystemName="ActCode"
        displayName="emergency" />
  <statusCode code="active" />
  <effectiveTime>
    <low value="20050927095000" inclusive="true" />
  </effectiveTime>
  <priorityCode code="EM" codeSystem="2.16.840.1.113883.5.7" codeSystemName="ActPriority"
                displayName="emergency" />
  <confidentialityCode code="N" codeSystem="2.16.840.1.113883.5.25" codeSystemName="Confidentiality" displayName="normal" />
  <reasonCode code="MEDNEC" codeSystem="2.16.840.1.113883.5.8" codeSystemName="ActReason"
             displayName="Medical_Necessity" />
  <subject typeCode="SBJ">
    <patient>
      <id root="2.16.840.1.113883.19.3.2409" extension="444551234" displayable="true" />
      <addr use="HP">
        <streetAddressLine>2222 Home Street</streetAddressLine>
        <city>Ann Arbor</city>
        <state>MI</state>
        <postalCode>99999</postalCode>
        <country>USA</country>
      </addr>
      <patientPerson>
        <name>Adam A Everyman</name>
        <administrativeGenderCode code="M" codeSystem="2.16.840.1.113883.5.1"
                                  codeSystemName="AdministrativeGender" displayName="Male" />
        <birthTime value="19550304" />
      </patientPerson>
    </patient>
  </subject>
</encounterEvent>
Using data safely

- Always check the device
- Multimodality monitoring is about elucidating underlying physiology, not making treat / no treat decisions.
  - Not all physiologic processes can or should be ‘treated’
  - Trust the numbers but don’t treat the numbers
    - $P_{bt}O_2$ is 15 mmHg – is intervention required?
    - $P_{bt}O_2$ was 30 mmHg an hour ago and now it is 20 mmHg – something has changed, what is it!?!
- For clinical decisions - trust change more than absolute numbers.
- Changes frequently occur LONG BEFORE clinical exam changes are observed.
  - Don’t say: “I didn’t believe the data changes were real because there wasn’t a clinical exam change”
- You might not have ALL the data needed to make a definitive clinical decision. Order another test (e.g., CT Perfusion scan)
- Treat data change like a clinical exam change, with possibility of helping figuring out what is happening.
Conclusions

- 3 problems (collection, display, analysis)
  - Solve data collection first.
  - Open format (e.g., SQL database) best to accommodate display and analysis possibilities

- Weigh effort of double (triple) charting compared to technical / political effort to get an electronic data feed.

- Think about how to use data safely. Start by trying to understand physiology rather than absolute numbers

- Big data change = clinical exam change

- Ask vendors of all types about data connectivity – the more we all ask for it the easier this will become!