INSIDE THE BLACK BOX

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Associate Professor of Clinical Neurology and Neurological Surgery
Director, Neuro-ICU
Columbia-Presbyterian Medical Center
Monitoring in the ICU

• What we have been
• Where we are now
ORIGINAL MOTION PICTURE SOUNDTRACK
MUSIC COMPOSED AND CONDUCTED BY JERRY GOLDSMITH

COMA
Three Phases of the History of Neuromonitoring

- Phase 1: Clinical neuromonitoring
  - 1960-1980
  - React to clinical events
Monitoring in the ICU

- **CV**: ECG, MAP, CVP, PAD, CO, troponin
- **Pulmonary**: O₂ sat, ABGs, CXR
- **ID**: Temperature
- **Renal**: I/O’s, creatinine, electrolytes
- **Endocrine**: Glucose
- **Heme**: CBC, coags
- **Neuro**: Exam!
Intracranial Mass Effect
Sternal Rub
Three Phases of the History of Neuromonitoring

- Phase 1: Clinical neuromonitoring
  - 1960-1980
  - React to clinical events
- Phase 2: Physiological neuromonitoring
  - 1980-2000
  - React to pathophysiological events
ICP

MANNITOL

CPP

Graph showing changes in ICP and CPP over time with annotations indicating 40g, 20g, and 20g doses.
Monitoring in the ICU

- What we have been
- Where we are now
- Where we need to go
ICP: Dead End Box
Neuro-ICU Brain Monitoring

- ICP
- cEEG
- CBF
- SJVO2
- TCD
- Brain Tissue O2
- Microdialysis

COURTESY DR PAUL VESPA
Integrated NICU Monitoring System of the Future

- cEEG
- ICP/CPP
- TCD/CBF
- JVO2 sat/AVDO2
- Brain Tissue Oxygenation
- Intracerebral Microdialysis

→ Chaos and Confusion

- BP
- CI
- Temp
- pO2
- ETCO2
- Sedation

COURTESY DR MICHAEL DEGEORGIA
Integrated NICU Multimodality System of the Future

Physiologic Brain Health
- cEEG
- ICP/CPP
- TCD/CBF
- JVO2 sat/AVDO2
- Brain Tissue Oxygenation
- Intracerebral Microdialysis

Physiologic Drivers
- BP
- CI
- Temp
- pO2
- ETCO2
- Sedation

Integrated NICU Monitoring System

Event Monitoring
Real Time Physiologic Interrelationships
Post Hoc “Data Mining”

NICU Records

ADAPTED COURTESY OF DR MICHAEL DEGEORGIA
PLUG AND PLAY
新たな収穫 - 佐野元春のオルタナティヴな精神

text: 吉原聖洋
The two essential components of an effective MMM system

CONNECTIVITY

USER INTERFACE
Multimodal monitoring during hypothermia

anisocoria: l>r

Hetastarch
Glycerol
Thiopental
Mannitol
Hetastarch
THAM
Body positioning

COURTESY DR THORSTEN STEINER
Three Phases of the History of Neuromonitoring

• Phase 1: Clinical neuromonitoring
  • 1960-1980
  • React to clinical events

• Phase 2: Physiological neuromonitoring
  • 1980-2000
  • React to pathophysiological events

• Phase 3: Neurophysiological decision support
  • 21st Century
  • Understand and manage complex physiology to prevent pathophysiological events
Integrated NICU Multimodality System of the Future

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ADAPTED COURTESY OF DR MICHAEL DEGEORGIA
Brain Oxygen Tension Monitoring: LICOX

- Assesses adequacy of cerebral perfusion
- Early warning of differences between brain tissue oxygen supply and demand
- Independent, sensitive outcome prediction
Effect of Brain Tissue Hypoxia on Outcome
Subarachnoid Hemorrhage

DURATION OF CRITICAL HYPOXIA: <10 MM HG

Good Outcome | Poor Outcome

<30 minutes | 65% | 35%  

>30 minutes | 23% | 77%  

P=0.05

Kett-White R et al. Neurosurgery. 2001; 50; 1213-21
Scatterplot of Cerebral Perfusion Pressure by Brain Oxygen
Time Period 900-1000 Minutes

$r^2 = 0.6934$
The two essential components of an effective MMM system

CONNECTIVITY

USER INTERFACE
A scratch?  
Your arm’s off!  
No, it isn’t.
Cerebral Autoregulation

Adapted with permission from Varon J, Marik PE. Chest. 2000;118:214-227.
Scatterplot of Cerebral Perfusion Pressure by Brain Oxygen

Time Period 900-1000 Minutes

$r^2 = 0.6934$
Integrated NICU Multimodality System of the Future

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Integrated NICU Monitoring System

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NICU Records

ADAPTED COURTESY OF DR MICHAEL DEGEORGIA
Real Time Physiologic Interrelationships
Things I Hate About My GE Bedside Monitor

- I can’t analyze time trend data easily at the bedside
- I can only look at data over time
- I can’t adjust the Y axis scale
- I can only view data on the X axis over 24 hours, no longer
- I can only look at 3 variables at a time
- I can’t see therapeutic interventions
Heart rate
Respirations
SBP
DBP
MAP
Temp-Foley
Temp-Brain
Serum Glucose
Serum Osmolality
ICP
CPP
FiO2
Minute Ventilation
Peak Airway Press
VO2
ETCO2
Phenylephrine
Dobutamine
Propofol
Fentanyl
Mannitol (Bolus)
Phenytoin (Bolus)
PbrO2
CBF(ml/100g/min)
EEG Alpha/Delta
EEG Total Power
MD-Glucose
MD-Glutamate
MD-Lactate
MD-Pyruvate
MD-Glutamate

TIME TRENDS
SCATTER PLOTS
CPP-PbrO2 OPTIMIZATION
SEIZURE DETECTION
TEMP ANALYSIS

HR

MAP

RR

Temp-Foley

ETCO2
| JOSEPH HERMAN  
| 435-67-89  |

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<th>Heart rate</th>
<th>Respirations</th>
<th>SBP</th>
<th>DBP</th>
<th>MAP</th>
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<th>Temp-Brain</th>
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<td>Mannitol (Bolus)</td>
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| TIME TRENDS | SCATTER PLOTS | CPP-PBrO2 OPTIMIZATION | SEIZURE DETECTION | TEMP ANALYSIS |

- **HR**
- **MAP**
- **RR**
- **Temp-Foley**
- **ETCO2**

**TIME**

**TRENDS**

**SCATTER PLOTS**

**CPP-PBrO2 OPTIMIZATION**

**SEIZURE DETECTION**

**TEMP ANALYSIS**

**HR**

**MAP**

**RR**

**Temp-Foley**

**ETCO2**

**MANNITOL**

**MANNITOL**
Heart rate
Respirations
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DBP
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MD-Glutamate
Central Area In Lesion Side

Percentage EEG Change By Mannitol

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<th></th>
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<tr>
<td>BETA</td>
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Points During And After Mannitol
TIME SAMPLED: 2 DAYS AGO (JAN 24 8:00 – JAN 25 8:00)
Target CPP
95-105 mm Hg

R²: ICP•PbrO₂
R²: MAP•PbrO₂

SLIDE COURTESY DR J MICHAEL SCHMIDT
Heart rate
Respirations
SBP
DBP
MAP
Temp-Foley
Temp-Brain
Serum Glucose
Serum Osmolality
ICP
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FiO2
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EEG Alpha/Delta
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MD-Pyruvate
MD-Glutamate

NCSE
midaz
What the clinician wants from ICU information platforms

- Connectivity: Boxes that talk to each other
- Real time data on rounds at the bedside
- Open data architecture that allows innovation
- Logical clean graphical user interface developed by clinicians