Supplemental Material

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Supplemental Table 1: Description of Experts

Question	Round One, n(%)	Round Two, n(%)
What is your training background?**		
Neurology	13 (43.3)	18 (51.4)
Pediatric neurology	5 (16.7)	5 (14.3)
Neurosurgery	4 (13.3)	4 (11.4)
Intensive care	2 (6.7)	2 (5.7)
Internal medicine	2 (6.7)	2 (5.7)
Nursing	1 (3.3)	2 (5.7)
Anesthesia	1 (3.3)	1 (2.9)
Emergency medicine	0 (0)	1 (2.9)
Pediatrics	2 (6.7)	1 (2.9)
Surgery	0 (0)	0 (0)
Which is your current primary practice?**		
Neurocritical care	22 (73.3)	29 (82.9)
Neurosurgery	3 (10)	5 (14.3)
Epilepsy and/or clinical neurophysiology	2 (6.7)	4 (11.4)
Intensive care	2 (6.7)	4 (11.4)
Neurology	1 (3.3)	4 (11.4)
Pediatrics	0 (0)	3 (8.6)
Pediatric critical care	2 (6.7)	1 (2.9)
Emergency medicine	0 (0)	1 (2.9)
Neurohospitalist	1 (3.3)	0 (0)
Anesthesia	0 (0)	0 (0)
Internal medicine	0 (0)	0 (0)
Surgery	0 (0)	0 (0)
Which population do you primarily care for?**		
Adults	24 (80)	30* (85.7)
Children	6* (20)	6* (17.1)
Neonates	1* (3.3)	2* (5.7)
How many years have you been in independent practice?		
None (trainee)	0 (0)	0 (0)
Up to 5 years	5 (16.7)	5 (14.3)
6-10 years	9 (30)	12 (34.3)
> 11 years	16 (53.3)	18 (51.4)
What is your academic research time allocation (%)?		
>50% of my time is protected for research	10 (33.3)	11 (31.4)
26-50% of my time is dedicated research time	7 (23.3)	5 (14.3)
10-25% of my time dedicated research time	8 (26.7)	11 (31.4)
<10% of my time is dedicated research time	3 (10)	5 (14.3)
100% of my time is dedicated to clinical duties	1 (3.3)	2 (5.7)
Non-academic clinical practice	1 (3.3)	1 (2.9)

*One respondent in Round 1 selected both children and neonates; one respondent in Round 2 selected adult and child populations, and two selected children and neonates.

**Respondents were able to select more than one choice

Supplemental Table 2: Invited Non-Participants (n=23)

Primary Specialty	n(%)
Neurocritical Care	15 (65)
Intensive Care	5 (22)
Clinical neurophysiology	2 (9)
Pediatric Critical Care	1 (4)

Supplemental Table 3: Areas of Consensus Including Statistical Results

	Round Two		Round Three	
	Median [IQR]	IQR Difference	Strongly Agree (%)	Strongly Disagree (%)
Clinical Considerations for Utility of MNM				
Level of consciousness	8 [7-9]	2	19 (100)	0 (0)
Underlying disease or diagnosis	8 [7-8]	1		
Potential risk for secondary brain injuries or secondary neurodeterioration	8 [8-9]	1		
Structural imaging findings	7 [6.5-7]	0.5		
Confounding factors clouding the neurological examination	7 [6-8]	2	18 (95)	1 (5)
Desire to understand the pathophysiology underlying brain dysfunction (e.g., diffuse vs focal injury processes)	7 [6.5-8]	1.5		
Guiding individualized management decisions	8 [8-8.5]	0.5		
Informing goals or thresholds for targeted management	8 [8-8]	0		
A*bstaining from* or *de-escalating* a potential therapy or treatment that might cause harm?	8 [7-8]	1		
Case Presentations: Invasive and/or Non-invasive Monitoring				
Non-surgical traumatic brain injury who remains comatose (GCS 8 or less) after initial resuscitation	9 [8-9]	1		
Surgical traumatic brain injury who remains comatose (GCS 8 or less) after appropriate evacuation and/or decompression?	9 [8-9]	1		
Aneurysmal subarachnoid hemorrhage who remains comatose (Hunt-Hess 4-5) after initial resuscitation and/or treatment of hydrocephalus?	9 [8-9]	1		
Aneurysmal subarachnoid hemorrhage who has developed vasospasm or vasospasm-associated delayed cerebral ischemia and who is comatose or ventilated on sedation?	9 [8.5-9]	0.5		
Supratentorial (lobar or basal ganglia) intracerebral hemorrhage without intraventricular hemorrhage who is comatose (GCS 8 or less) after initial resuscitation and/or treatment of hydrocephalus?	7 [7-8]	1		
Supratentorial (lobar or basal ganglia) intracerebral hemorrhage with intraventricular hemorrhage who is comatose (GCS 8 or less) after initial resuscitation and/or treatment of hydrocephalus?	7 [7-8.5]	1.5		
Minimum Necessary Devices				
Intracranial pressure (ICP)	9 [9-9]	0		
Cerebral perfusion pressure (CPP)*	8 [8-9]	1		

End-tidal capnography (ETCO2)	8 [7-8.5]	1.5		
Brain tissue oxygen (PbtO2 or PtiO2)	8 [7-8.5]	1.5		
Continuous scalp EEG	9 [8-9]	1		
Quantitative pupillometry	8 [7-8.75]	1.75		
Arterial blood pressure (ABP)	9 [9-9]	0		
Cardiac telemetry (ECG)	9 [8-9]	1		
Continuous core body temperature*	9 [8-9]	1		
Plethysmography (SpO2)	9 [8-9]	1		
Minimum Necessary Access				
Bedside visualization or display of a single, current (live) measurement value, e.g., a single numeric value displayed on a device at that moment in time visible in a patient care area	8 [7-8]	1		
Bedside visualization or display of single measurement trended over time, e.g., a graph of a time-series displayed on a device visible in a patient care area	8 [7-8]	1		
Bedside visualization or display of multiple, current (live) measurement values together on the same screen, e.g., multiple numeric measurement values from different devices displayed on the same screen and visible in a patient care area*	8 [8-9]	1		
Bedside visualization or display of multiple measurements trended over time and aligned on the same screen, e.g., a graph of several time-series from different devices displayed on the same screen and visible in a patient care area*	9 [8-9]	1		
Access to data with high temporal resolution (1 or more data points every minute) including clinically standard data such as heart rate, arterial blood pressure in addition to neuromonitoring-specific data	8 [7-8]	1		
Access to data at waveform resolution, such as ECG waveforms, arterial blood pressure or intracranial pressure waveforms, or EEG signals	8 [7.5-9]	1.5		
Electronic Health Record display (in a table or graph) of multiple different measurement values together on a single panel, tab, or screen	8 [7-8]	1		
Ability to annotate neuromonitoring data at bedside to indicate clinical events or other contextual data*	8 [8-9]	1		
Ability to display neuromonitoring data at bedside linked with annotations to indicate clinical events or other contextual data*	8 [8-9]	1		
Ability to display neuromonitoring data at bedside linked with Electronic Health Record information, e.g., laboratory values or medication administration information	8 [7-8]	1		
Ability to manipulate data visualization or display at bedside, e.g., zooming in or out (time scaling), scrolling back and forth in time, or selecting which neuromonitoring measurements to display	8 [7-9]	2	22 (100)	0 (0)
Ability to visualize or display neuromonitoring data in real-time remotely (from a separate reading room or from home)	9 [7.5-9]	1.5		

Ability to manipulate and review displayed neuromonitoring data in real-time remotely (from a separate reading room or from home), e.g., choosing specific neuromonitoring measurements to display or zooming in or out of the data	8 [8-9]	1		
Ability to display neuromonitoring data remotely linked with bedside annotations that indicate clinical events or other contextual data	8 [7-9]	2	21 (95)	1 (5)
Ability to display neuromonitoring data remotely linked with Electronic Health Record information, e.g., laboratory values or medication administration information	8 [7-9]	2	20 (91)	2 (9)
Ability to set alarms or thresholds to alert staff at bedside, e.g., via flashing colors or alarm sounds	7 [7-8]	1		
Bedside visualization or display of summary or aggregate data such as "Area Under the Curve", "Burden" or "Dose" on a device visible in a patient care area.	8 [7-9]	2	20 (91)	2 (9)
Ability to access neuromonitoring data in real-time for use in data analytic tools either through a network interface or hardware connection.	8 [7-8]	1		
Minimum Necessary Work				
Most intensivists staffing an ICU and caring for patients with brain injuries are able to adequately integrate and interpret multimodality neuromonitoring data as part of daily clinical care in order to make management decisions**	3 [3-3]	0		
Most intensivists staffing an ICU and caring for patients with brain injuries do have adequate time to fully review all available multimodality neuromonitoring data as part of daily clinical care**	3 [2-3]	1		
Most intensivists staffing an ICU and caring for patients with brain injuries have all the necessary technology to integrate and interpret multimodality neuromonitoring data as part of daily clinical care**	2 [1-3]	2	1 (5)	21 (95)
Most intensivists staffing an ICU and caring for patients with brain injuries have technology sufficient to troubleshoot device errors and to identify artifactual or erroneous multimodality neuromonitoring data. *,**	2 [1-3]	2	1 (5)	21 (95)
Most intensivists staffing an ICU and caring for patients with brain injuries would find regularly written reports summarizing multimodality neuromonitoring data and providing clinical interpretation/correlation to be helpful in making clinical decisions as part of daily clinical care.	8 [7-8.5]	1.5		
The integration and interpretation of multimodality neuromonitoring requires access to raw data for data manipulation outside of the devices on which data is measured, e.g., for pre-processing/cleaning, aggregation, integration with other data, computational analytics, and/or statistical analysis.*	9 [8-9]	1		
The integration and interpretation of multimodality neuromonitoring data requires review of a variety of time-scales - from hours to days of data - in order to	9 [8-9]	1		

make clinically meaningful inferences from the information.				
The integration and interpretation of multimodality neuromonitoring requires specific skill or expertise to synthesize multiple data trends over time that reflect disease trajectory.	9 [8-9]	1		
The integration and interpretation of multimodality neuromonitoring requires skill or expertise that is not routinely developed by any single fellowship training programs that exist currently.	7 [6-9]	3	18 (82)	1 (5)
The integration and interpretation of multimodality neuromonitoring requires integration with both brain-specific data and systemic data traditionally measured during critical care (e.g., hemodynamic information).	9 [8-9]	1		
The integration and interpretation of multimodality neuromonitoring requires clinical context and that 'clinical correlation' is a central component of this process.	9 [8-9]	1		
The application and maintenance of equipment and technologies related to multimodality neuromonitoring is time intensive for a clinician independent of other clinical duties.	8 [7-9]	2	18 (82)	0 (0)
The synthesis and interpretation of multiple neuromonitoring data trends is time intensive for a clinician independent of other clinical duties.	8 [7-9]	2	18 (82)	0 (0)
Existing billing codes for other neurophysiologic procedures such as continuous video EEG monitoring (e.g., CPT® 95720) or intraoperative monitoring (e.g., CPT® 95941) adequately capture the work of multimodality neuromonitoring. **	2.5 [1-4]	3	1 (5)	17 (76)
Operationalizing MNM				
Provide for bedside users (e.g., clinical care team) an interface that facilitates an understanding of multiple parameters in the context of a specific disease process.	8 [7-8]	1		
Provide for bedside users (e.g., clinical care team) an interface that displays trend data on a single screen that can be used to manipulate and explore data.	8 [7.5-8]	0.5		
Enhance clinical confidence in our monitoring data by using software tools to identify or remove artifacts within real-time monitoring data that limits clinical interpretation by bedside users (e.g., clinical care team).	8 [7-8.5]	1.5		
Identify necessary Information Technology (IT) or Clinical Engineering personnel to overcome technological hurdles that limit access to monitoring data at my institution.	8 [7-8]	1		
Invest in education for bedside users (e.g., clinical care team) focused on understanding the parameters being measured and why.	8 [8-9]	1		
Invest in education for bedside users (e.g., clinical care team) focused on learning how to respond to monitoring data.	8 [7-9]	2	17 (77)	2 (9)

Standardize who is monitored and by which technologies.	8 [7-8]	1		
Develop clinical management algorithms based on patterns within monitoring data that can be identified by bedside users (e.g., clinical care team)	8 [6-8]	2	17 (77)	1 (5)
Identify physiologic thresholds and other findings during monitoring that would mandate clinical action or trigger clinical judgement.	7 [7-8]	1		
Access to a standardized lexicon of patterns that occur in and between physiologic variables associated with specific underlying biology or clinical relevance.	7 [7-8]	1		
Enlist staff and/or trainees to provide expertise in the technical and clinical aspects of our monitoring devices at all times (including nights or weekends).	7 [7-8]	1		
Staff member to act as a 'clinical champion' to encourage the use of monitoring.	8 [7-9]	2	17 (77)	1 (5)
Directly engage the multiple stakeholders that are involved in the day-to-day care for patients undergoing monitoring, including neurocritical care, neurosurgery, neurology and others.	8 [7.5-8.5]	1		
Schedule regularly held multidisciplinary case conferences to discuss relevant monitoring cases with others involved in day-to-day care for patients undergoing monitoring.	8 [7-9]	2		
Training Background				
Specific training or expertise is required to adequately prepare clinicians to understand and interpret multimodality neuromonitoring information.	9 [8-9]	1		
Clinical training programs in emergency medicine provide a knowledge base that adequately prepares clinicians to understand and interpret multimodality neuromonitoring information. **	3 [2-4]	2	0 (0)	19 (95)
Clinical training programs in specialty nursing provide a knowledge base that adequately prepares clinicians to understand and interpret multimodality neuromonitoring information. **	3 [2-4.5]	2.5	0 (0)	19 (95)
Education Format				
Hands-on workshops or seminars	7 [7-8]	1		
Clinical practice or bedside teaching	8 [7-9]	2	20 (91)	2 (9)
Development of a core curriculum	8 [6.5-9]	2.5	16 (73)	1 (5)
Supervised performance and demonstration of procedural competency	7 [6.5-8.5]	2	18 (82)	2 (9)

CPT = Current Procedural Terminology®, EEG = electroencephalography, GCS = Glasgow Coma Scale, ICU = intensive care unit, IQR = interquartile range, MNM = multimodality neuromonitoring

Agreement was defined as a median Likert score of ≥ 7 or ≤ 3 while *consensus* was defined as > 70% within the lowest or highest tertile and an IQR difference ≤ 1.75. Items achieving consensus during discussion-based round three must have a) agreement during round two plus b) at least 70% voting strong agreement and < 10% voting strong disagreement.

*Indicates items that lacked inter-round stability during Round 2

**Indicates items for which there was consensus *dis*agreement

Supplemental Table 4: Areas of Agreement without Consensus

Clinical Considerations for Utility of MNM
Potential for harm related to placement of invasive neuromonitoring devices or devices with more than minimal risk relative to benefit
Time point within a specific disease course (e.g., number of days following an injury)
The institution's comfort level in the use of neuromonitoring
Case Presentations: Invasive Monitoring Only
Metabolic encephalopathy (e.g., severe hyperglycemia or hyponatremia) clinical or radiographic concern for cerebral edema who has an abnormal neurological exam but is able to follow commands (GCS 9-12)*
Requiring deep sedation, anesthesia, or paralytics for non-neurological reasons (e.g., ventilatory support) with no structural injury on imaging at-risk for unstable hemodynamics*
Severe acute respiratory failure (e.g., acute respiratory distress syndrome [ARDS]) requiring venovenous extracorporeal membrane oxygenation (VV-ECMO)*
Case Presentations: Invasive and/or Non-invasive Monitoring
Sinus thrombosis or posterior reversible encephalopathy syndrome (PRES) with cerebral edema at risk for herniation who is comatose (GCS 8 or less)
Following cardiac arrest with short downtime, no past medical history, and normal head CT who is comatose after rewarming (i.e., > 24 hours after arrest)
Following cardiac arrest with short downtime, no past medical history and clinical or radiographic concern for cerebral edema
Case Presentations: Non-invasive Monitoring Only
Aneurysmal subarachnoid hemorrhage with an abnormal neurological exam but able to follow commands (Hunt-Hess 3-4) after initial resuscitation and/or treatment of hydrocephalus
Hemispheric ischemic stroke with malignant edema either not yet committed to surgical decompression or following adequate surgical decompression?
Super-refractory status epilepticus requiring multiple anesthetic medications?
Infectious or presumed infectious encephalitis/meningitis who is comatose (GCS 8 or less) without evidence of seizures, hydrocephalus, or other causes of coma
Reversible cerebral vasoconstriction syndrome or other vasculopathy at risk for evolving ischemia who is comatose (GCS 8 or less)?
Following cardiac arrest with short downtime, no past medical history, and normal head CT who is comatose during targeted temperature management (i.e., within 24 hours of arrest)?
Following cardiac arrest with no past medical history and normal head CT who is comatose and develops clinical post-anoxic myoclonus early after injury?
Metabolic encephalopathy (e.g., severe hyperglycemia or hyponatremia) with clinical or radiographic concern for cerebral edema who is comatose (GCS 8 or less)?
Cytokine release syndrome-related encephalopathy (e.g., due to SARS-CoV-2 or CAR T-cell neurotoxicity syndrome) or other inflammatory condition with clinical or radiographic concern for cerebral edema who is comatose (GCS 8 or less)
Fulminant hepatic failure with clinical or radiographic concern for cerebral edema who is comatose (West Haven Stage 4)
Cardiopulmonary failure requiring veno-arterial extracorporeal membrane oxygenation (VA-ECMO)
Sepsis who is comatose (GCS 8 or less) due to underlying septic encephalopathy or shock
Genetic metabolic disorder with or without seizures at-risk for metabolic decompensation and global cerebral edema who is comatose (GCS 8 or less)?
Severe ARDS requiring VV-ECMO
Minimum Necessary Devices
Optimal Cerebral Perfusion Pressure (CPP_{opt})
Cerebrovascular Autoregulation

Quantitative EEG (qEEG)
Autonomic Function (e.g., heart rate variability) *
Minimum Necessary Access
Electronic Health Record capture of single measurement values, e.g., within flowsheet rows or tables
Ability to annotate neuromonitoring data remotely to indicate clinical events or other contextual data
Ability to access neuromonitoring data for use in other software packages by downloading from a hardware interface (e.g., bedside download of data through a USB drive)
Ability to access neuromonitoring data for use in other software packages through software or server-based interface (e.g., data is accessible from a server)
Ability to display therapeutic decision-making aids, decision support tools or diagnostic/management algorithms for clinical staff at bedside, e.g., interactive prompts or stepwise clinical guidance.
Ability to access neuromonitoring data in real-time for use in a secure cloud-based platform capable of deploying data analytic tools (e.g., machine learning algorithms).
Minimum Necessary Work
Existing billing codes for critical care (e.g., CPT® 99291 or 99292) adequately capture the work of multimodality neuromonitoring*
Operationalizing MNM
Enhance clinical confidence in our monitoring data by providing transparency for the methods used to derive calculations or summary statistics.
Provide remote access to monitoring data for members of the clinical care team.
Disseminate existing evidence-based data and consensus-based care protocols to bedside users (e.g., clinical care team).
Hire or enlist technologists, advanced practice providers and/or nursing educators to be available to provide expertise in the technical and clinical aspects of our monitoring devices at all times (including nights or weekends).
Institutional provision of adequate time and support for a dedicated staff member to perform clinical interpretation of real-time monitoring data (e.g., a neuromonitoring 'reader').
Daily communication of information obtained from monitoring was made available either through notes in the Electronic Health Record or by sending emails to the clinical care team (e.g., neuromonitoring 'reports').
A *centralized* expert reader through remote tele-health review of patients undergoing monitoring at my institution.
Develop a business plan that financially incentivizes my hospital to invest in necessary capital expenditures.
Reimbursement strategy (e.g., a dedicated CPT® code for neuromonitoring) to support dedicated clinicians to perform interpretation and reporting of monitoring data for use by clinical care teams in caring for patients with brain injuries.
Training Background
All clinical training programs for practitioners who will be taking care of brain injured patients should provide education dedicated specifically to understanding the technical and clinical aspects of multimodality neuromonitoring.
Only clinical training programs at centers that regularly use multimodality neuromonitoring should provide education dedicated specifically to understanding the technical and clinical aspects of multimodality neuromonitoring
An adequate knowledge base to understand and interpret multimodality neuromonitoring information does not require additional training in clinical neurophysiology or EEG regardless of primary specialty training*
An adequate knowledge base to understand and interpret multimodality neuromonitoring information does require additional training in clinical neurophysiology or EEG regardless of primary specialty training.
Education Format
Case-based learning
Multidisciplinary case conferences
Recognition through an online certification process supported through collaborative partners interested in advancing neuromonitoring

Recognition through a certification process supported through national societies (e.g., Neurocritical Care Society [NCS], American Clinical Neurophysiology Society [ACNS], or the American Society of Neurophysiologic Monitoring [ASNM]).

CAR = chimeric antigen receptor, CPT = Current Procedural Terminology®, CT = computed tomography, EEG = electroencephalography, GCS = Glasgow Coma Scale, ICU = intensive care unit, IQR = interquartile range, MNM = multimodality neuromonitoring

*Indicates *dis*agreement with the item without consensus

Supplemental Table 5: Areas without Agreement

Clinical Considerations for Utility of MNM
The perception of the medical team that a certain prognosis is inevitable
Age (either too young or too old)
Presence of additional organ dysfunction (e.g., stress cardiomyopathy or acute respiratory distress syndrome [ARDS])
Case Presentations: Invasive Monitoring Only
Aneurysmal subarachnoid hemorrhage who has an abnormal neurological exam but is able to follow commands (Hunt-Hess 3-4) after initial resuscitation and/or treatment of hydrocephalus?
Hemispheric ischemic stroke at-risk for malignant edema not yet committed to surgical decompression?
Hemispheric ischemic stroke with malignant edema following adequate surgical decompression?
Super-refractory status epilepticus requiring multiple anesthetic medications?
Infectious or presumed infectious encephalitis/meningitis who is comatose (GCS 8 or less) without evidence of seizures, hydrocephalus, or other causes of coma?
Reversible cerebral vasoconstriction syndrome or other vasculopathy at risk for evolving ischemia who is comatose (GCS 8 or less)?
Following cardiac arrest with short downtime, no past medical history, and normal head CT who is comatose during targeted temperature management (i.e., within 24 hours of arrest)?
Following cardiac arrest with no past medical history and normal head CT who is comatose and develops clinical post-anoxic myoclonus early after injury?
Metabolic encephalopathy (e.g., severe hyperglycemia or hyponatremia) clinical or radiographic concern for cerebral edema who is comatose (GCS 8 or less)?
Cytokine release syndrome-related encephalopathy (e.g., due to SARS-CoV-2 or CAR T-cell neurotoxicity syndrome) or other inflammatory condition clinical or radiographic concern for cerebral edema who is comatose (GCS 8 or less)
Fulminant hepatic failure clinical or radiographic concern for cerebral edema who is comatose (West Haven Stage 4)
Cardiopulmonary failure requiring veno-arterial extracorporeal membrane oxygenation (VA-ECMO)
Sepsis who is comatose (GCS 8 or less) due to underlying septic encephalopathy or shock
Genetic metabolic disorder with or without seizures at-risk for metabolic decompensation and global cerebral edema who is comatose (GCS 8 or less)?
Case Presentations: Invasive and/or Non-invasive Monitoring
Non-surgical traumatic brain injury who has an abnormal neurological exam but is able to follow commands (GCS 9-12) after initial resuscitation?
Surgical traumatic brain injury who has an abnormal neurological exam but is able to follow commands (GCS 9-12) after appropriate evacuation and/or decompression?
Supratentorial (lobar or basal ganglia) intracerebral hemorrhage +/- intraventricular extension who has an abnormal neurological exam but is able to follow commands (GCS 9-12)?
Non-surgical traumatic brain injury who has an abnormal neurological exam but is able to follow commands (GCS 9-12) after initial resuscitation with spinal cord injury or significant long bone fractures that limit motor examination and require early or urgent major surgery?
Case Presentations: Non-invasive Monitoring Only

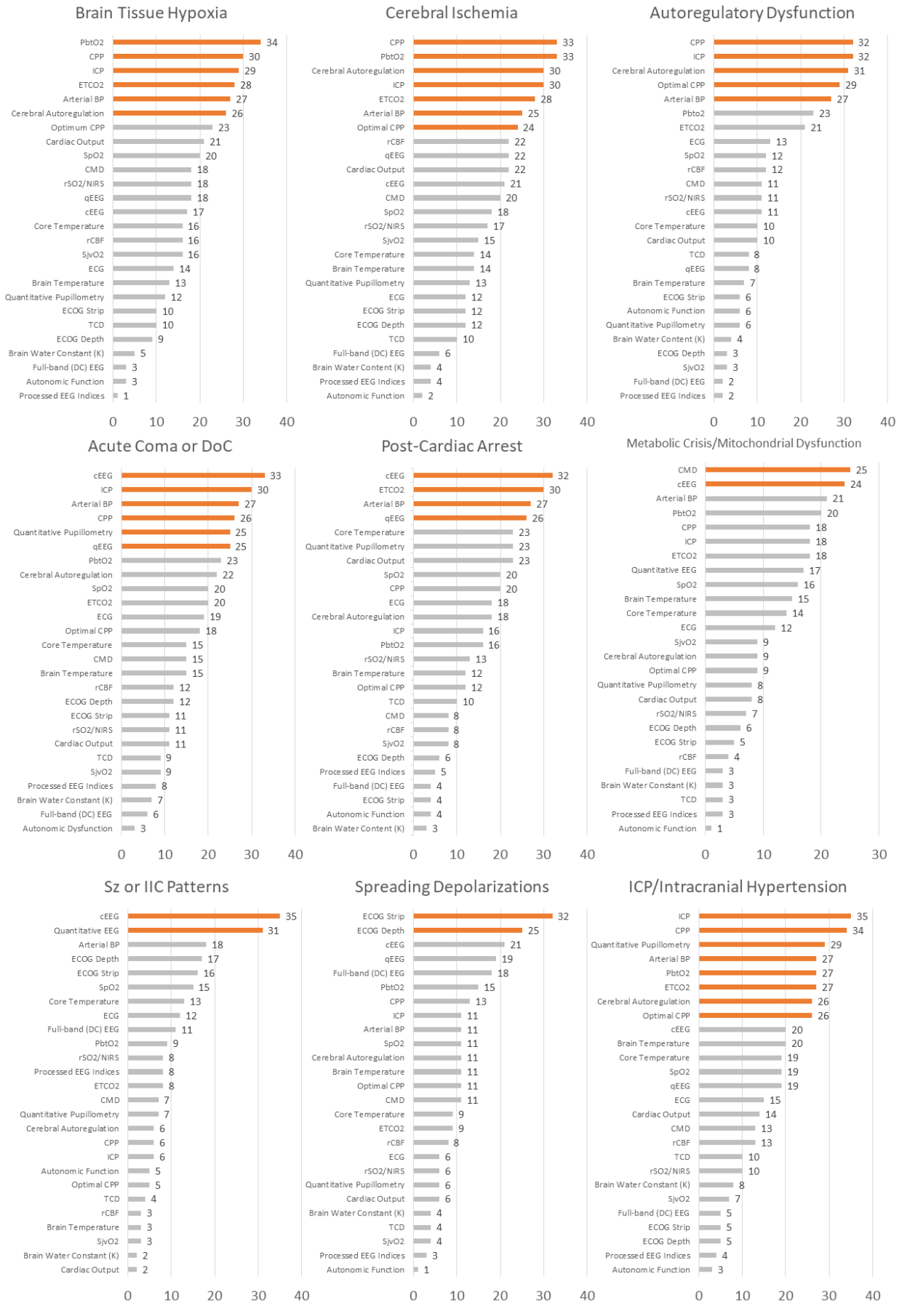
Metabolic encephalopathy (e.g., severe hyperglycemia or hyponatremia) clinical or radiographic concern for cerebral edema who has an abnormal neurological exam but is able to follow commands (GCS 9-12)?
No structural injury on imaging and who requires deep sedation, anesthesia, or paralytics for non-neurological reasons (e.g., ventilatory support) and is at-risk for unstable hemodynamics?
Minimum Necessary Devices
Cardiac output (including associated measures of intravascular volume)
Jugular venous oxygen (SjvO2)
Regional oxygen saturation (rSO2) using near-infrared spectroscopy (NIRS) or other optical imaging technology
Regional cerebral blood flow (rCBF)
Brain temperature
Brain water constant (K)
Cerebral microdialysis: lactate and pyruvate
Cerebral microdialysis: brain tissue glucose
Cerebral microdialysis: glutamate
Cerebral microdialysis: glycerol
Electrocorticography: single-wire or depth electrode
Electrocorticography: strip electrode
Full-band (DC or near-DC) EEG recordings
Processed EEG indices of anesthesia/sedation depth
Extended-duration (> 30 min) or frequent (> 1 daily) transcranial Doppler ultrasonography
Minimum Necessary Access
Ability to set alarms or thresholds to alert staff remotely, e.g., through push notifications or email
Minimum Necessary Work
I feel that most intensivists staffing an ICU and caring for patients with brain injuries have clinical knowledge of brain physiology sufficient to use multimodality neuromonitoring data in making clinical decisions as part of daily clinical care.
I feel that the integration and interpretation of multimodality neuromonitoring data is part of neurocritical care and is NOT distinct from the work of either critical care or general clinical duties as it exists currently.
I feel that the integration and interpretation of multimodality neuromonitoring data is part of neurocritical care and would not be distinct from the work of either critical care or general clinical duties if a simplified user interface is provided for bedside users without expertise and/or experience.
Operationalizing MNM (no items unable to reach agreement or consensus)
Training Background
I feel that clinical training programs in the neurological specialties (e.g., neurocritical care or neurophysiology) provide a knowledge base that adequately prepares clinicians to understand and interpret multimodality neuromonitoring information.
I feel that clinical training programs in anesthesia and/or intensive care provide a knowledge base that… prepares clinicians to understand & interpret multimodality neuromonitoring information.
I feel that clinical training programs in neurosurgery provide a knowledge base that adequately prepares clinicians to understand and interpret multimodality neuromonitoring information.
I feel that an adequate knowledge base to understand and interpret multimodality neuromonitoring information requires additional training in data management or health informatics.
I feel that an adequate knowledge base to understand and interpret multimodality neuromonitoring information requires additional training in bioengineering, signal analysis, or time-series analysis
Education Format
I feel that training and expertise necessary to understand and interpret multimodality neuromonitoring is best acquired through simulation or sim-based learning.
I feel that training and expertise necessary to understand and interpret multimodality neuromonitoring is best acquired through online, self-paced modules.
I feel that training and expertise necessary to understand and interpret multimodality neuromonitoring is best acquired through dedicated fellowship training.

I feel that training and expertise necessary to understand and interpret multimodality neuromonitoring should be recognized through formal board certification (e.g., through the United Council for Neurological Subspecialties or the American Board of Medical Specialties).

CAR = chimeric antigen receptor, CPT = Current Procedural Terminology®, CT = computed tomography, EEG = electroencephalography, GCS = Glasgow Coma Scale, ICU = intensive care unit, IQR = interquartile range, MNM = multimodality neuromonitoring

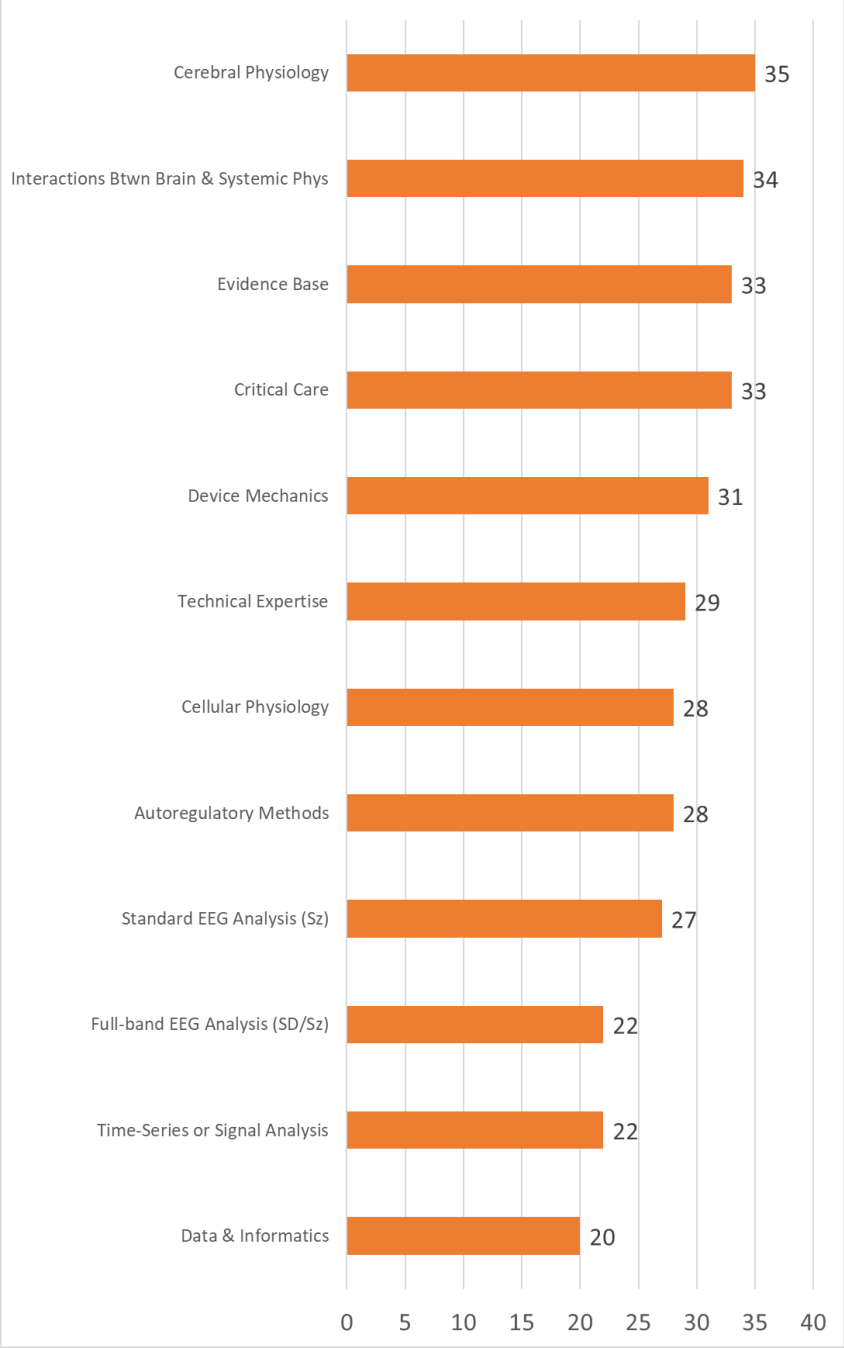
* 'Continuous' is defined by data sampled no less frequently than every 6 hours. The majority of devices that fulfill this criterion are sampled more frequently, and there should be a preference for waveform or second-to-second data where applicable

Supplemental Figure 1: Context-specific Devices and Measurements



Bar graphs reflecting devices and measurements felt to be important for each context of use. Contexts were chosen to reflect secondary brain injury patterns and participants were asked to select any modalities that would be necessary to detect these pathophysiologies. Participants were instructed not to consider cost or local availability of devices and to assume that any and all devices were available to them for a given patient. The x-axis reflects the number of participants that selected each concept out of a total of 35. Items in orange achieved agreement, defined as selection by >2/3 of participants; those in gray did not meet the threshold for agreement. In some cases, there was agreement among pediatric specialists but not adult specialists. These included the use of regional oxygen saturation and cardiac output monitoring for brain tissue hypoxia; regional oxygen saturation and quantitative EEG for cerebral ischemia; end-tidal CO2 monitoring for acute coma or disorders of consciousness; cardiac output monitoring and core body temperature in post-cardiac arrest; arterial blood pressure and end-tidal CO2 monitoring for mitochondrial dysfunction and metabolic crisis; and both cEEG and extended-duration TCD monitoring for ICP or intracranial hypertension. In contrast, adult specialists were more likely to select invasive measurements including cerebral autoregulation metrics and optimum CPP estimation, brain tissue oxygen monitoring, and cerebral microdialysis. The proportion of adult vs pediatric participants selecting these devices and measurements was not statistically significant, however.

Supplemental Figure 2: Reporting Elements



Bar graphs reflecting reporting elements that participants would find important each day as the attending physician responsible for a patient undergoing clinical neuromonitoring in order to make

clinical decisions. The y-axis reflects the number of participants that selected each item. Items endorsed by > 23 participants achieved the threshold for agreement.

The Practice of Clinical Multimodality Neuromonitoring: an eDelphi Consensus Statement

Problem & Rationale

'Neuromonitoring' refers to the use of any frequent (ideally, continuously) measure of brain physiology that can be performed at the bedside with a focus on detecting clinically-important events in real-time. This is distinct from 'neurodiagnostic' technologies such as radiological tests (CT, MRI) or tests ordered only infrequently or as-needed, such as somatosensory evoked potentials or serum-based biomarkers.

'Multimodality neuromonitoring' refers to the use of more than one data source to provide a more comprehensive assessment of the brain. This usually implies a higher level of complexity reserved for selected at-risk patients, typically in an ICU setting with limitations in neurological exam, such as coma.

The work that is involved in providing 'multimodality neuromonitoring' might encompass technical knowledge of devices that are only used to monitor specific patients, a familiarity with accessing or analyzing time-series data offline, and/or an ability to derive insights from physiologic data by looking at information across time.

However, there is no consensus for what constitutes the clinical PRACTICE of multimodality neuromonitoring. Specifically, gaps exist in defining the following:

a. appropriate contexts of use or indications,
b. minimum and/or necessary monitoring devices and measurements,
c. minimum access requirements for clinical use (such as data integration and visualization),
d. work required to clearly differentiate from critical care or other related services (e.g. continuous video-EEG reporting),
e. training necessary to provide clinically-meaningful interpretation

The clinical integration, interpretation, and reporting of multimodality neuromonitoring data has not crystallized as a distinct clinical service; questions exist as to whether it is a distinct service at all. This is in large part because there is no agreed-upon definition of 'multimodality neuromonitoring'.

This survey serves as Round 1 of an eDelphi process designed to provide consensus for these areas of uncertainty with goal of providing standards by which multimodality neuromonitoring may be distinguished as a unique diagnostic specialty.

Respondant Information

The eDelphi process is strictly anonymous and no identifying information should be shared. Below are questions that will be used to characterize the participant cohort.

1

What is your training background?

- ○ Neurology
- ○ Pediatric Neurology
- ○ Neurosurgery
- ○ Internal Medicine
- ○ Pediatrics
- ○ Anesthesia
- ○ Surgery
- ○ Emergency Medicine
- ○ Nursing
- ○ Other

2

Which is your current primary practice?

- ○ Neurocritical Care
- ○ Intensive Care
- ○ Anesthesia
- ○ Pediatric Critical Care
- ○ Pediatrics
- ○ Neurology
- ○ Epilepsy and/or Clinical Neurophysiology
- ○ Internal Medicine
- ○ Neurosurgery
- ○ Emergency Medicine
- ○ Surgery
- ○ Other

3

Which population do you primarily care for?

- ○ Adults
- ○ Children
- ○ Neonates
- ○ Other

4

How many years have you been in independent practice?

- ◯ None (trainee)
- ◯ up to 5 years
- ◯ 6-10 years
- ◯ > 11 years

5

What is your academic research time allocation (%)?

- ◯ NA; I work in a community/private practice setting
- ◯ 100% of my time is dedicated to clincal duties
- ◯ <10% of my time is dedicated research time
- ◯ 10-25% of my time dedicated research time
- ◯ 26-50% of my time is dedicated research time
- ◯ >50% of my time is protected for research
- ◯ Other

Please select each of the physiologic measurement modalities below that you personally have used at some point in your career to provide or recommend care for patients:

N.B. This question assumes the routine use of clincally-standard non-invasive and arterial blood pressure, cardiac telemetry, peripheral oxygen saturation , and core body temperature monitoring

- [ ] Intracranial Pressure (ICP)
- [ ] Cardiac Output (including associated measures of intravascular volume)
- [ ] Cerebral Perfusion Pressure (CPP)
- [ ] Optimal Cerebral Perfusion Pressure (CPPopt)
- [ ] Cerebral Autoregulation
- [ ] End-Tidal Capnography (ETCO2)
- [ ] Brain Tissue Oxygen (PbtO2 or PtiO2)
- [ ] Jugular Venous Oxygen (SjvO2)
- [ ] Regional Oxygen Saturation (rSO2) using Near-Infrared Spectroscopy (NIRS) or other optical imaging technology
- [ ] Regional Cerebral Blood Flow (rCBF)
- [ ] Brain Temperature
- [ ] Brain Water Constant (K)
- [ ] Cerebral Microdialysis
- [ ] Continuous Scalp EEG
- [ ] Electrocorticography: Single-wire or Depth Electrode
- [ ] Electrocorticography: Strip Electrode
- [ ] Full-band (DC or near-DC) EEG Recordings
- [ ] Quantitative EEG
- [ ] Processed EEG Indices of Anesthesia/Sedation Depth

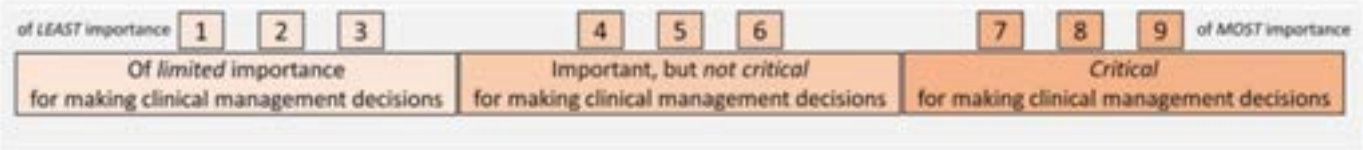
- [ ] Quantitative Pupillometry
- [ ] Extended-Duration (> 30 min) or Frequent (> 1 daily) Transcranial Doppler Ultrasonography (TCD)
- [ ] Autonomic Function (e.g. heart rate variability)

Contexts of Use: Clinical Considerations

Context of use is defined as the users, tasks, equipment, and the physical and social environments in which a system or service is used (ISO 9241-11:1998, 3.5, modified). In this case, we refer to the medical environment, e.g. the type of problem that a patient may have for which multimodality neuromonitoring might be useful or helpful.

7

How important is level of consciousness when determining the clinical utility of mulitmodality neuromonitoring for a patient?



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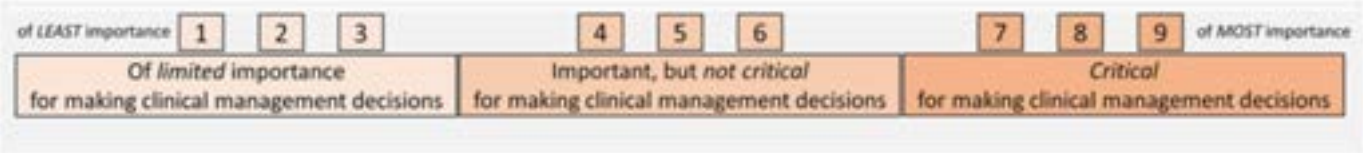
8

How important is the underlying disease or diagnosis when determining the clinical utility of multimodality neuromonitoring for a patient?



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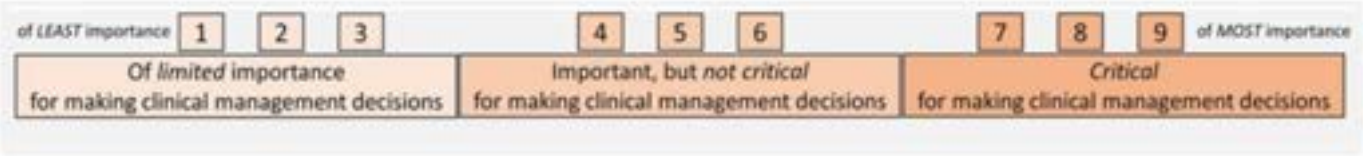
9

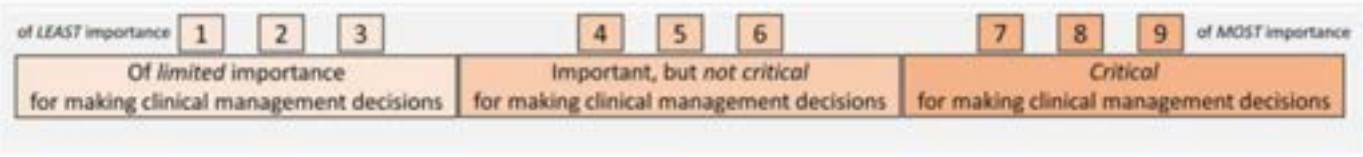
How important is the potential risk for secondary brain injuries or secondary neurodeterioration when determining the clinical utility of multimodality neuromonitoring for a patient?



1 2 3 4 5 6 7 8 9

10

How important is the potential for harm related to placement of neuromonitoring devices relative to their benefit when determining the clinical utility of multimodality neuromonitoring for a patient?



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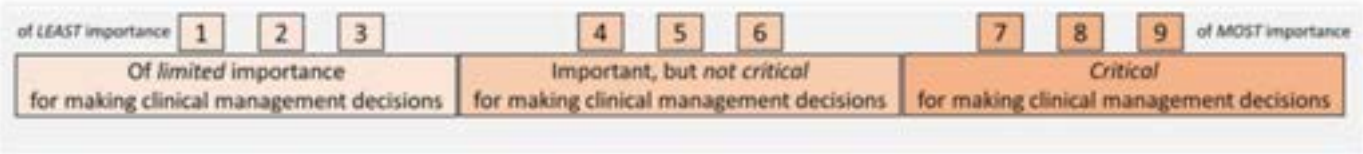
11

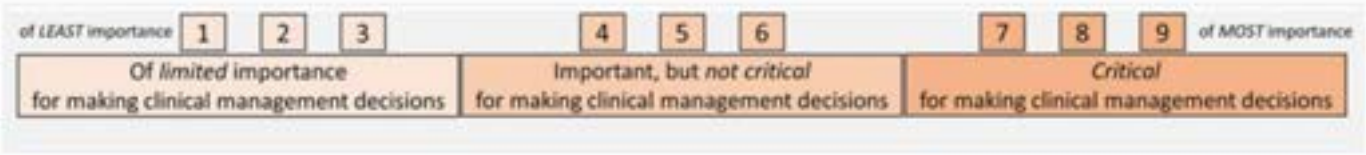
How important is perceived prognosis when determining the clinical utility of multimodality neuromonitoring for a patient?



1 2 3 4 5 6 7 8 9

12

How important is age (either too young or too old) when determining the clinical utility of multimodality neuromonitoring for a patient?



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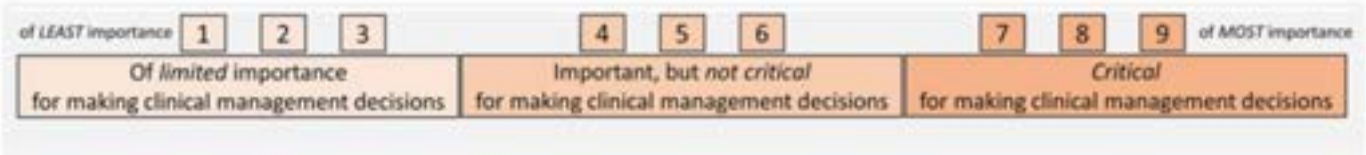
13

How important are structural imaging findings when determining the clinical utility of multimodality neuromonitoring for a patient?



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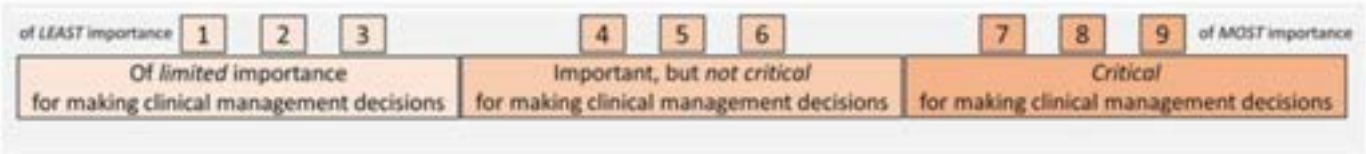
14

How important is multimodality neuromonitoring in guiding individualized management decisions for a patient?



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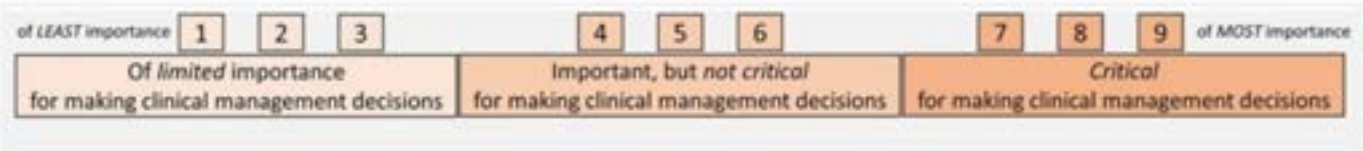
15

How important is multimodality neuromonitoring in informing goals or thresholds for targeted management in a patient?



1 2 3 4 5 6 7 8 9

16

What other clinical considerations might inform the clinical utility of multimodality neuromonitoring for a patient?

Contexts of Use: Case Presentations

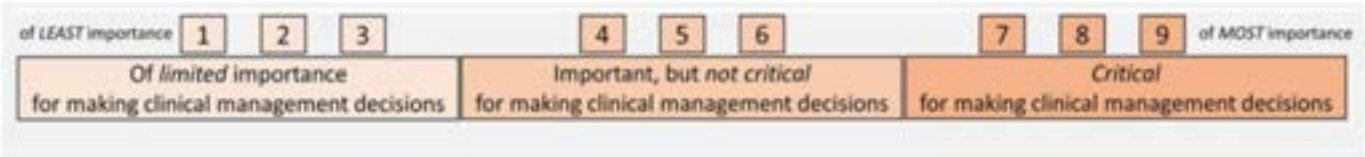
For all questions, please do not consider cost, relative contraindications such as coagulopathy, or barriers to the placement of intracranial devices. If you would not be primarily caring for a patient as described by the questions below, answer to the best of your ability based on your experience.

If your primary practice is PEDIATRIC, answer all questions below considering a child admitted to the Pediatric Intensive Care Unit for which there is a reasonable prognostic outlook and for whom all available brain monitoring - invasive and/or noninvasive as available at your institution - would be used.

If your primary practice involves ADULTS only, answer all questions below considering a middle-aged adult admitted to the Intensive Care Unit for which there is a reasonable prognostic outlook and for whom all available brain monitoring - invasive and/or noninvasive as available at your institution - would be used.

17

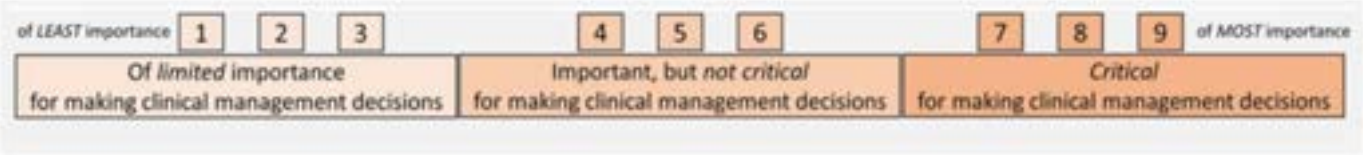
How important is multimodality neuromonitoring in a patient presenting with:
a.) non-surgical traumatic brain injury
b.) who remains comatose (GCS 8 or less) after initial resuscitation?



1 2 3 4 5 6 7 8 9

18

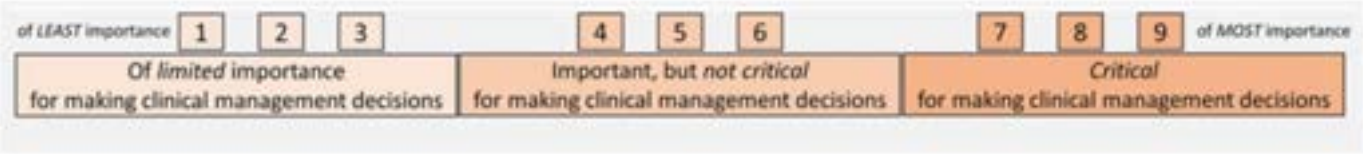
How important is multimodality neuromonitoring in a patient presenting with:
a.) surgical traumatic brain injury
b.) who remains comatose (GCS 8 or less) after appropriate evacuation and/or decompression?



1 2 3 4 5 6 7 8 9

19

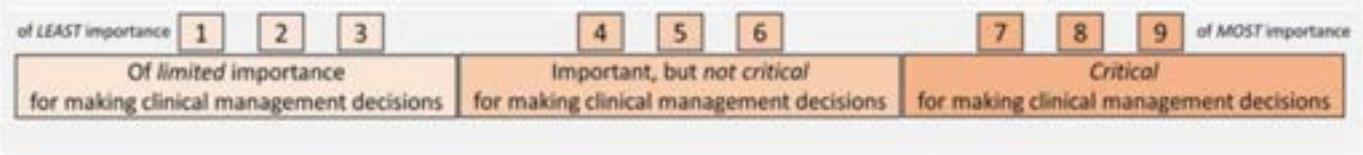
How important is multimodality neuromonitoring in a patient presenting with:
a.) non-surgical traumatic brain injury
b.) who has an abnormal neurological exam but is able to follow commands (GCS 9-12) after initial resuscitation?



1 2 3 4 5 6 7 8 9

20

How important is multimodality neuromonitoring in a patient presenting with:
a.) surgical traumatic brain injury
b.) who has an abnormal neurological exam but is able to follow commands (GCS 9-12) after appropriate evacutation and/or decompression?



1 2 3 4 5 6 7 8 9

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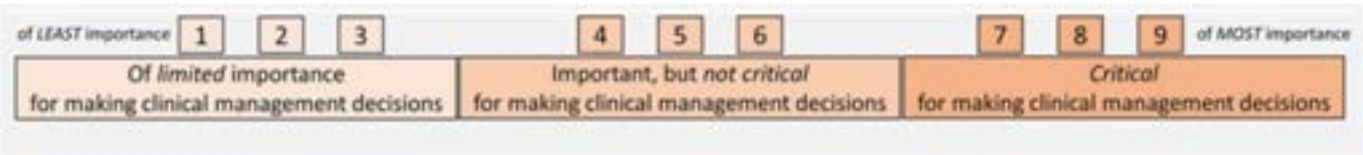
21

How important is multimodality neuromonitoring in a patient presenting with:
a.) aneurysmal subarachnoid hemorrhage
b.) who remains comatose (Hunt-Hess 4-5) after initial resuscitation and/or treatment of hydrocephalus?



1 2 3 4 5 6 7 8 9

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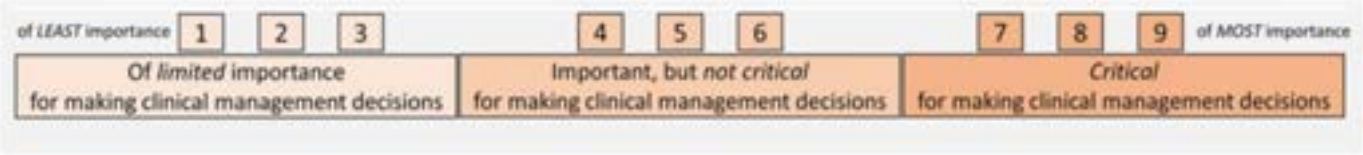
22

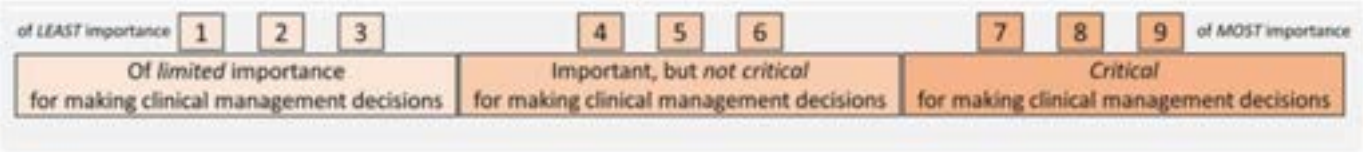
How important is multimodality neuromonitoring in a patient presenting with:
a.) aneurysmal subarachnoid hemorrhage
b.) who has an abnormal neurological exam but is able to follow commands (Hunt-Hess 3-4) after initial resuscitation and/or treatment of hydrocephalus?



1 2 3 4 5 6 7 8 9

23

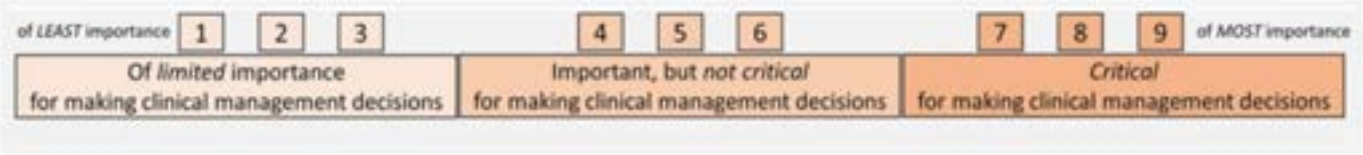
How important is multimodality neuromonitoring in a patient presenting with:
a.) aneurysmal subarachnoid hemorrhage
b.) who has developed vasospasm or vasospasm-associated delayed cerebral ischemia
c.) and who is comatose or ventilated on sedation?



1 2 3 4 5 6 7 8 9

24

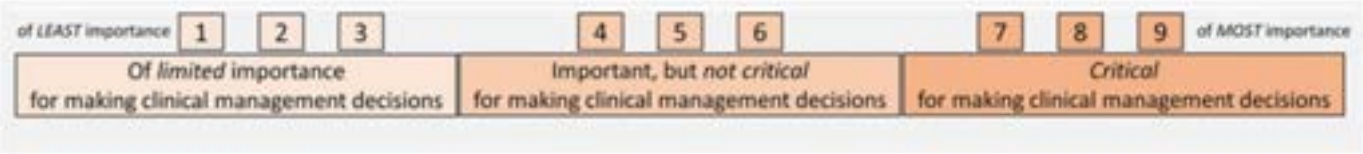
How important is multimodality neuromonitoring in a patient presenting with:
a.) supratentorial (lobar or basal ganglia) intracerebral hemorrhage without intraventricular hemorrhage
b.) who is comatose (GCS 8 or less)?



1 2 3 4 5 6 7 8 9

25

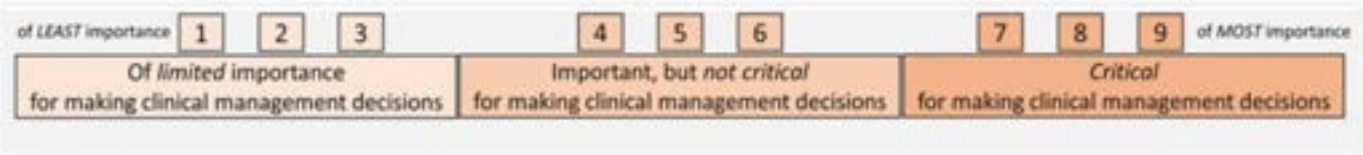
How important is multimodality neuromonitoring in a patient presenting with:
a.) supratentorial (lobar or basal ganglia) intracerebral hemorrhage with intraventricular extension
b.) who is comatose (GCS 8 or less) after treatment of hydrocephalus?



1 2 3 4 5 6 7 8 9

26

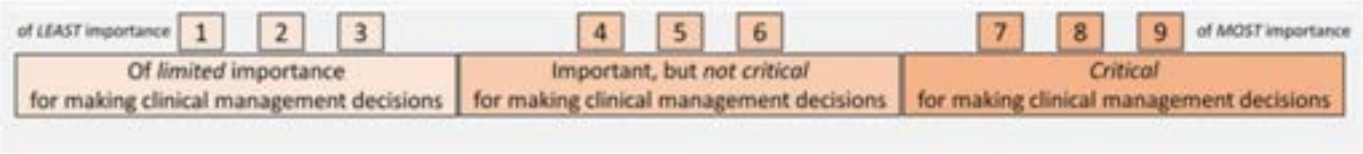
How important is multimodality neuromonitoring in a patient presenting with:
a.) supratentorial (lobar or basal ganglia) intracerebral hemorrhage +/- intraventricular extension
b.) who has an abnormal neurological exam but is able to follow commands (GCS 9-12)?



1 2 3 4 5 6 7 8 9

27

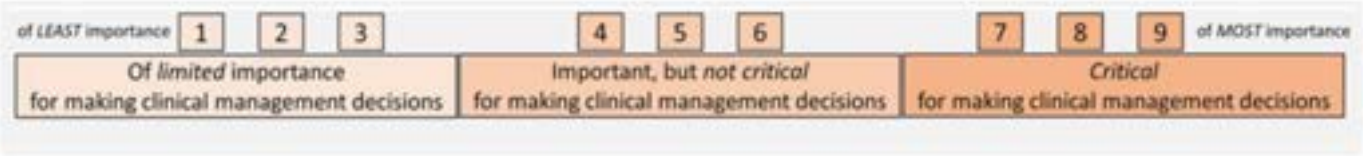
How important is multimodality neuromonitoring in a patient presenting with:
a.) hemispheric ischemic stroke at-risk for malignant edema not yet committed to surgical decompression?



1 2 3 4 5 6 7 8 9

28

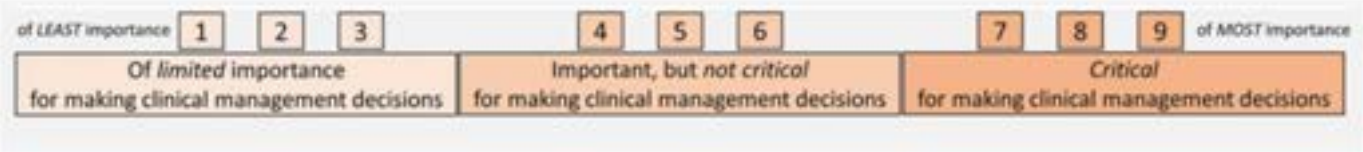
How important is multimodality neuromonitoring in a patient presenting with:
a.) hemispheric ischemic stroke with malignant edema following adequate surgical decompression?



1 2 3 4 5 6 7 8 9

29

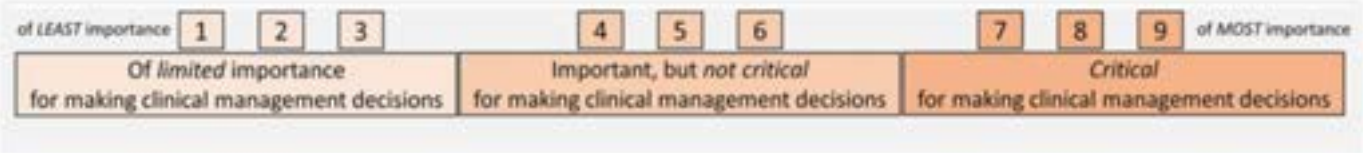
How important is multimodality neuromonitoring in a patient presenting with:
a.) super-refractory status epilepticus requiring multiple anesthetic medications?



1 2 3 4 5 6 7 8 9

30

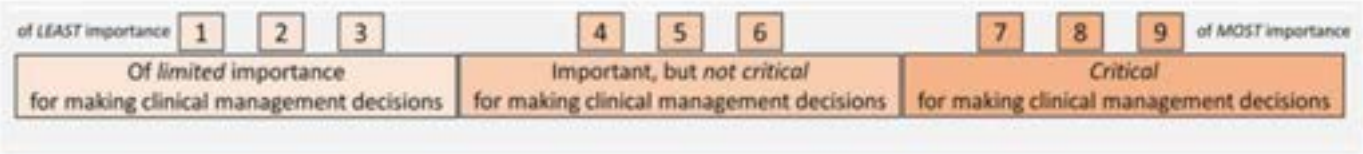
How important is multimodality neuromonitoring in a patient presenting with:
a.) infectious or presumed infectious encephalitis/meningitis
b.) who is comatose (GCS 8 or less) without evidence of seizures, hydrocephalus, or other causes of coma?



1 2 3 4 5 6 7 8 9

31

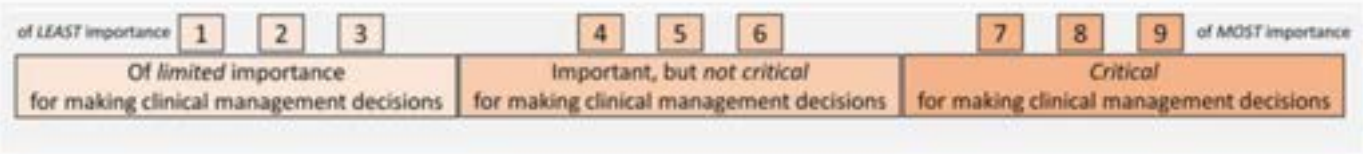
How important is multimodality neuromonitoring in a patient presenting with:
a.) sinus thrombosis or PRES with cerebral edema at risk for herniation
b.) who is comatose (GCS 8 or less)?



1 2 3 4 5 6 7 8 9

32

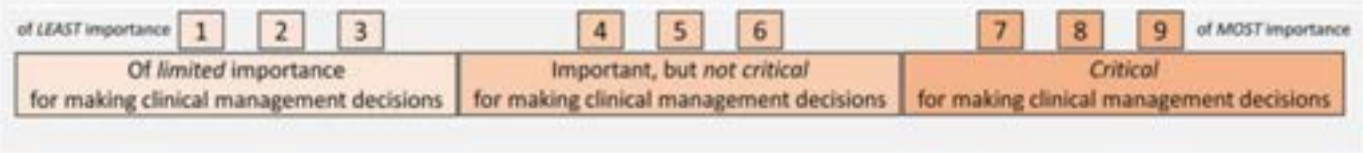
How important is multimodality neuromonitoring in a patient presenting with:
a.) RCVS or other vasculopathy at risk for evolving ischemia
b.) who is comatose (GCS 8 or less)?



1 2 3 4 5 6 7 8 9

33

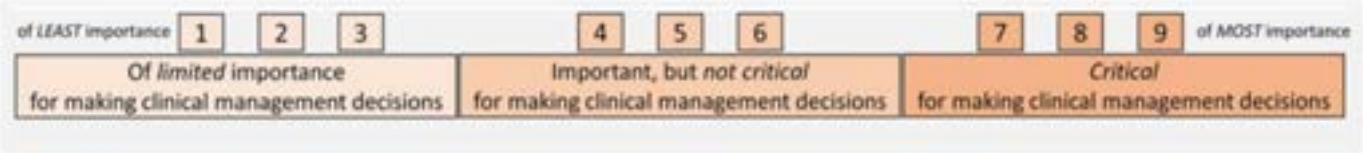
How important is multimodality neuromonitoring in a patient presenting with:
a.) following cardiac arrest
b.) with short downtime, no past medical history, and normal CT
c.) who is comatose during TTM (i.e. within 24 hours of arrest)?



1 2 3 4 5 6 7 8 9

34

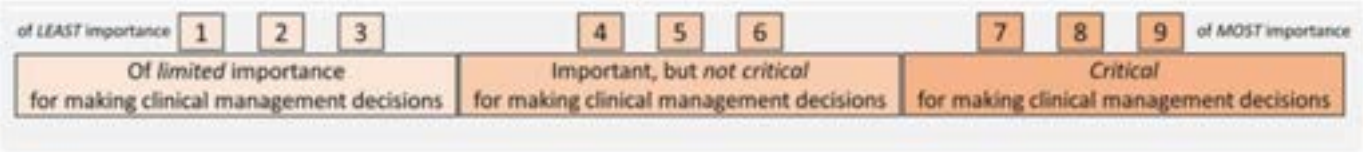
How important is multimodality neuromonitoring in a patient presenting with:
a.) following cardiac arrest
b.) with short downtime, no past medical history, and normal CT
c.) who is comatose after rewarming (i.e. > 24 hours after arrest)?



1 2 3 4 5 6 7 8 9

35

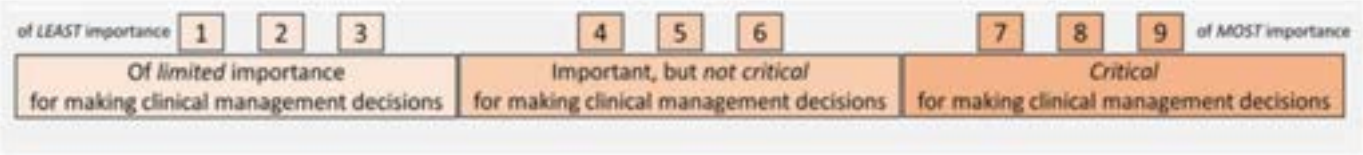
How important is multimodality neuromonitoring in a patient presenting with:
a.) following cardiac arrest
b.) with no past medical history and normal CT
c.) who is comtaose and develops clinical post-anoxic myoclonus early after injury?



1 2 3 4 5 6 7 8 9

36

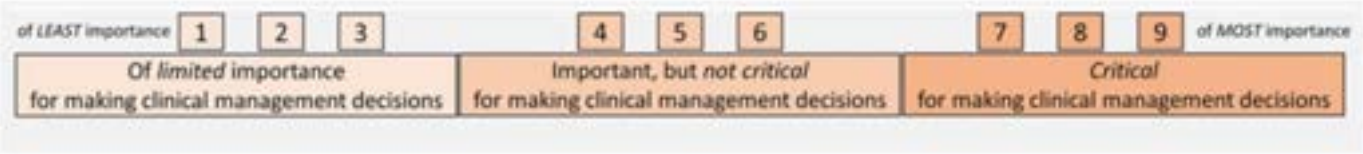
How important is multimodality neuromonitoring in a patient presenting with:
a.) following cardiac arrest
b.) with short downtime, no past medical history
c.) and clinical or radiographic concern for cerebral edema?



1 2 3 4 5 6 7 8 9

37

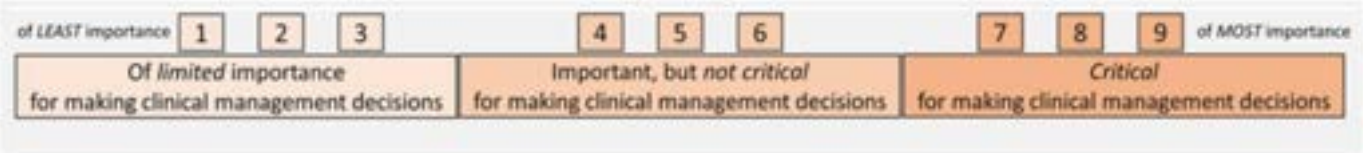
How important is multimodality neuromonitoring in a patient presenting with:
a.) metabolic encephalopathy (e.g. severe hyperglycemia or hyponatremia)
b.) clinical or radiographic conern for cerebral edema
c.) who is comatose (GCS 8 or less)?



1 2 3 4 5 6 7 8 9

38

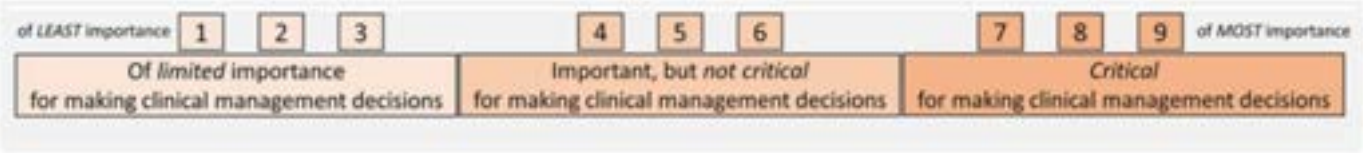
How important is multimodality neuromonitoring in a patient presenting with:
a.) metabolic encephalopathy (e.g. severe hyperglycemia or hyponatremia)
b.) clinical or radiographic concern for cerebral edema
c.) who has an abnormal neurological exam but is able to follow commands (GCS 9-12)?



1 2 3 4 5 6 7 8 9

39

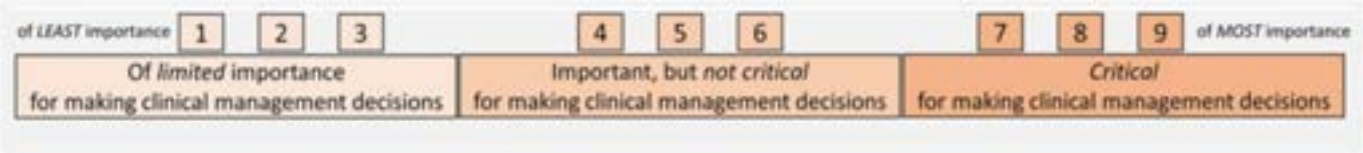
How important is multimodality neuromonitoring in a patient presenting with:
a.) cytokine release syndrome-related encephalopathy (e.g. COVID-related, CAR T-cell neurotoxicity syndrome) or other inflammatory condition
b.) clinical or radiographic concern for cerebral edema
c.) who is comatose (GCS 8 or less)



1 2 3 4 5 6 7 8 9

40

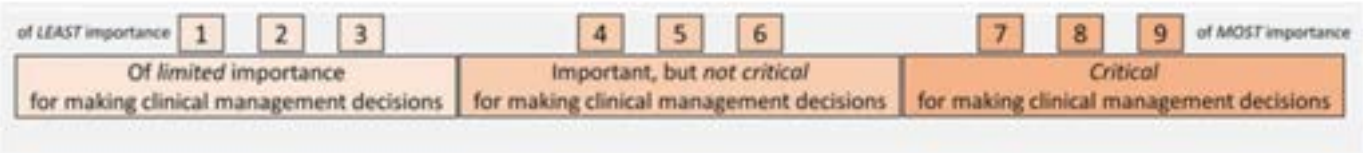
How important is multimodality neuromonitoring in a patient presenting with:
a.) fulminant hepatic failure
b.) clinical or radiographic concern for cerebral edema
c.) who is comatose (West Haven Stage 4)



1 2 3 4 5 6 7 8 9

41

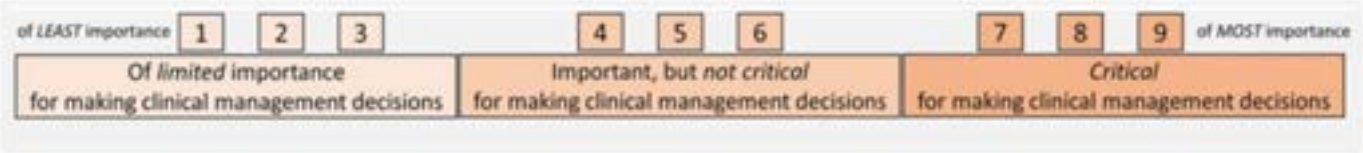
How important is multimodality neuromonitoring in a patient presenting with:
a.) cardiopulmonary failure requiring veno-arterial extracorporeal membrane oxygenation (VA-ECMO)



1 2 3 4 5 6 7 8 9

42

How important is multimodality neuromonitoring in a patient presenting with:
a.) sepsis
b.) who is comatose (GCS 8 or less) due to underlying septic encephalopathy or shock



1 2 3 4 5 6 7 8 9

43

Please indicate other diagnoses or disease states for which multimodality neuromonitoring might be important for clinical decision-making. Be as specific as possible.

Contexts of Use: BRAIN TISSUE HYPOXIA

For each of the questions below, please select EACH of the physiologic measurements that you feel are useful to detect and optimally manage BRAIN TISSUE HYPOXIA.

Select all that apply:

- [ ] Intracranial Pressure (ICP)
- [ ] Cardiac Output (including associated measures of intravascular volume)
- [ ] Cerebral Perfusion Pressure (CPP)
- [ ] Optimal Cerebral Perfusion Pressure (CPPopt)
- [ ] Cerebral Autoregulation
- [ ] End-Tidal Capnography (ETCO2)
- [ ] Brain Tissue Oxygen (PbtO2 or PtiO2)
- [ ] Jugular Venous Oxygen (SjvO2)
- [ ] Regional Oxygen Saturation (rSO2) using Near-Infrared Spectroscopy (NIRS) or other optical imaging technology
- [ ] Regional Cerebral Blood Flow (rCBF)
- [ ] Brain Temperature
- [ ] Brain Water Constant (K)
- [ ] Cerebral Microdialysis
- [ ] Continuous Scalp EEG
- [ ] Electrocorticography: Single-wire or Depth Electrode
- [ ] Electrocorticography: Strip Electrode
- [ ] Full-band (DC or near-DC) EEG Recordings
- [ ] Quantitative EEG
- [ ] Processed EEG Indices of Anesthesia/Sedation Depth
- [ ] Quantitative Pupillometry
- [ ] Extended-Duration (> 30 min) or Frequent (> 1 daily) Transcranial Doppler Ultrasonography (TCD)
- [ ] Autonomic Function (e.g. heart rate variability)

- [ ] Arterial Blood Pressure (ABP)
- [ ] Cardiac Telemetry (ECG)
- [ ] Plethysmography (SpO2)
- [ ] Continuous Core Body Temperature

Contexts of Use: CEREBRAL ISCHEMIA

For each of the questions below, please select EACH of the physiologic measurements that you feel are useful to detect and optimally manage CEREBRAL ISCHEMIA.

45

Select all that apply:

- [ ] Intracranial Pressure (ICP)
- [ ] Cardiac Output (including associated measures of intravascular volume)
- [ ] Cerebral Perfusion Pressure (CPP)
- [ ] Optimal Cerebral Perfusion Pressure (CPPopt)
- [ ] Cerebral Autoregulation
- [ ] End-Tidal Capnography (ETCO2)
- [ ] Brain Tissue Oxygen (PbtO2 or PtiO2)
- [ ] Jugular Venous Oxygen (SjvO2)
- [ ] Regional Oxygen Saturation (rSO2) using Near-Infrared Spectroscopy (NIRS) or other optical imaging technology
- [ ] Regional Cerebral Blood Flow (rCBF)
- [ ] Brain Temperature
- [ ] Brain Water Constant (K)
- [ ] Cerebral Microdialysis
- [ ] Continuous Scalp EEG
- [ ] Electrocorticography: Single-wire or Depth Electrode
- [ ] Electrocorticography: Strip Electrode
- [ ] Full-band (DC or near-DC) EEG Recordings
- [ ] Quantitative EEG
- [ ] Processed EEG Indices of Anesthesia/Sedation Depth
- [ ] Quantitative Pupillometry
- [ ] Extended-Duration (> 30 min) or Frequent (> 1 daily) Transcranial Doppler Ultrasonography (TCD)
- [ ] Autonomic Function (e.g. heart rate variability)

- [ ] Arterial Blood Pressure (ABP)
- [ ] Cardiac Telemetry (ECG)
- [ ] Plethysmography (SpO2)
- [ ] Continuous Core Body Temperature

Contexts of Use: AUTOREGULATORY DYSFUNCTION

For each of the questions below, please select EACH of the physiologic measurements that you feel are useful to detect and optimally manage AUTOREGULATORY DYSFUNCTION.

Select all that apply:

- [ ] Intracranial Pressure (ICP)
- [ ] Cardiac Output (including associated measures of intravascular volume)
- [ ] Cerebral Perfusion Pressure (CPP)
- [ ] Optimal Cerebral Perfusion Pressure (CPPopt)
- [ ] Cerebral Autoregulation
- [ ] End-Tidal Capnography (ETCO2)
- [ ] Brain Tissue Oxygen (PbtO2 or PtiO2)
- [ ] Jugular Venous Oxygen (SjvO2)
- [ ] Regional Oxygen Saturation (rSO2) using Near-Infrared Spectroscopy (NIRS) or other optical imaging technology
- [ ] Regional Cerebral Blood Flow (rCBF)
- [ ] Brain Temperature
- [ ] Brain Water Constant (K)
- [ ] Cerebral Microdialysis
- [ ] Continuous Scalp EEG
- [ ] Electrocorticography: Single-wire or Depth Electrode
- [ ] Electrocorticography: Strip Electrode
- [ ] Full-band (DC or near-DC) EEG Recordings
- [ ] Quantitative EEG
- [ ] Processed EEG Indices of Anesthesia/Sedation Depth
- [ ] Quantitative Pupillometry
- [ ] Extended-Duration (> 30 min) or Frequent (> 1 daily) Transcranial Doppler Ultrasonography (TCD)
- [ ] Autonomic Function (e.g. heart rate variability)

- [ ] Arterial Blood Pressure (ABP)
- [ ] Cardiac Telemetry (ECG)
- [ ] Plethysmography (SpO2)
- [ ] Continuous Core Body Temperature

Contexts of Use: METABOLIC CRISIS OR MITOCHONDRIAL DYSFUNCTION

For each of the questions below, please select EACH of the physiologic measurements that you feel are useful to detect and optimally manage METABOLIC CRISIS OR MITOCHONDRIAL DYSFUNCTION.

Select all that apply:

- [ ] Intracranial Pressure (ICP)
- [ ] Cardiac Output (including associated measures of intravascular volume)
- [ ] Cerebral Perfusion Pressure (CPP)
- [ ] Optimal Cerebral Perfusion Pressure (CPPopt)
- [ ] Cerebral Autoregulation
- [ ] End-Tidal Capnography (ETCO2)
- [ ] Brain Tissue Oxygen (PbtO2 or PtiO2)
- [ ] Jugular Venous Oxygen (SjvO2)
- [ ] Regional Oxygen Saturation (rSO2) using Near-Infrared Spectroscopy (NIRS) or other optical imaging technology
- [ ] Regional Cerebral Blood Flow (rCBF)
- [ ] Brain Temperature
- [ ] Brain Water Constant (K)
- [ ] Cerebral Microdialysis
- [ ] Continuous Scalp EEG
- [ ] Electrocorticography: Single-wire or Depth Electrode
- [ ] Electrocorticography: Strip Electrode
- [ ] Full-band (DC or near-DC) EEG Recordings
- [ ] Quantitative EEG
- [ ] Processed EEG Indices of Anesthesia/Sedation Depth
- [ ] Quantitative Pupillometry
- [ ] Extended-Duration (> 30 min) or Frequent (> 1 daily) Transcranial Doppler Ultrasonography (TCD)
- [ ] Autonomic Function (e.g. heart rate variability)

- [ ] Arterial Blood Pressure (ABP)
- [ ] Cardiac Telemetry (ECG)
- [ ] Plethysmography (SpO2)
- [ ] Continuous Core Body Temperature

Contexts of Use: SEIZURES OR ICTAL-INTERICTAL CONTINUUM PATTERNS

For each of the questions below, please select EACH of the physiologic measurements that you feel are useful to detect and optimally manage SEIZURES OR ICTAL-INTERICTAL CONTINUUM PATTERNS.

48

Select all that apply:

- [ ] Intracranial Pressure (ICP)
- [ ] Cardiac Output (including associated measures of intravascular volume)
- [ ] Cerebral Perfusion Pressure (CPP)
- [ ] Optimal Cerebral Perfusion Pressure (CPPopt)
- [ ] Cerebral Autoregulation
- [ ] End-Tidal Capnography (ETCO2)
- [ ] Brain Tissue Oxygen (PbtO2 or PtiO2)
- [ ] Jugular Venous Oxygen (SjvO2)
- [ ] Regional Oxygen Saturation (rSO2) using Near-Infrared Spectroscopy (NIRS) or other optical imaging technology
- [ ] Regional Cerebral Blood Flow (rCBF)
- [ ] Brain Temperature
- [ ] Brain Water Constant (K)
- [ ] Cerebral Microdialysis
- [ ] Continuous Scalp EEG
- [ ] Electrocorticography: Single-wire or Depth Electrode
- [ ] Electrocorticography: Strip Electrode
- [ ] Full-band (DC or near-DC) EEG Recordings
- [ ] Quantitative EEG
- [ ] Processed EEG Indices of Anesthesia/Sedation Depth
- [ ] Quantitative Pupillometry
- [ ] Extended-Duration (> 30 min) or Frequent (> 1 daily) Transcranial Doppler Ultrasonography (TCD)
- [ ] Autonomic Function (e.g. heart rate variability)

- [ ] Arterial Blood Pressure (ABP)
- [ ] Cardiac Telemetry (ECG)
- [ ] Plethysmography (SpO2)
- [ ] Continuous Core Body Temperature

Contexts of Use: SPREADING DEPOLARIZATIONS

For each of the questions below, please select EACH of the physiologic measurements that you feel are useful to detect and optimally manage SPREADING DEPOLARIZATIONS.

Select all that apply:

- [ ] Intracranial Pressure (ICP)
- [ ] Cardiac Output (including associated measures of intravascular volume)
- [ ] Cerebral Perfusion Pressure (CPP)
- [ ] Optimal Cerebral Perfusion Pressure (CPPopt)
- [ ] Cerebral Autoregulation
- [ ] End-Tidal Capnography (ETCO2)
- [ ] Brain Tissue Oxygen (PbtO2 or PtiO2)
- [ ] Jugular Venous Oxygen (SjvO2)
- [ ] Regional Oxygen Saturation (rSO2) using Near-Infrared Spectroscopy (NIRS) or other optical imaging technology
- [ ] Regional Cerebral Blood Flow (rCBF)
- [ ] Brain Temperature
- [ ] Brain Water Constant (K)
- [ ] Cerebral Microdialysis
- [ ] Continuous Scalp EEG
- [ ] Electrocorticography: Single-wire or Depth Electrode
- [ ] Electrocorticography: Strip Electrode
- [ ] Full-band (DC or near-DC) EEG Recordings
- [ ] Quantitative EEG
- [ ] Processed EEG Indices of Anesthesia/Sedation Depth
- [ ] Quantitative Pupillometry
- [ ] Extended-Duration (> 30 min) or Frequent (> 1 daily) Transcranial Doppler Ultrasonography (TCD)
- [ ] Autonomic Function (e.g. heart rate variability)

- [ ] Arterial Blood Pressure (ABP)
- [ ] Cardiac Telemetry (ECG)
- [ ] Plethysmography (SpO2)
- [ ] Continuous Core Body Temperature

Contexts of Use: INTRACRANIAL HYPERTENSION OR HERNIATION

For each of the questions below, please select EACH of the physiologic measurements that you feel are useful to detect and optimally manage INTRACRANIAL HYPERTENSION OR HERNIATION.

50

Select all that apply:

- [ ] Intracranial Pressure (ICP)
- [ ] Cardiac Output (including associated measures of intravascular volume)
- [ ] Cerebral Perfusion Pressure (CPP)
- [ ] Optimal Cerebral Perfusion Pressure (CPPopt)
- [ ] Cerebral Autoregulation
- [ ] End-Tidal Capnography (ETCO2)
- [ ] Brain Tissue Oxygen (PbtO2 or PtiO2)
- [ ] Jugular Venous Oxygen (SjvO2)
- [ ] Regional Oxygen Saturation (rSO2) using Near-Infrared Spectroscopy (NIRS) or other optical imaging technology
- [ ] Regional Cerebral Blood Flow (rCBF)
- [ ] Brain Temperature
- [ ] Brain Water Constant (K)
- [ ] Cerebral Microdialysis
- [ ] Continuous Scalp EEG
- [ ] Electrocorticography: Single-wire or Depth Electrode
- [ ] Electrocorticography: Strip Electrode
- [ ] Full-band (DC or near-DC) EEG Recordings
- [ ] Quantitative EEG
- [ ] Processed EEG Indices of Anesthesia/Sedation Depth
- [ ] Quantitative Pupillometry
- [ ] Extended-Duration (> 30 min) or Frequent (> 1 daily) Transcranial Doppler Ultrasonography (TCD)
- [ ] Autonomic Function (e.g. heart rate variability)

- [ ] Arterial Blood Pressure (ABP)
- [ ] Cardiac Telemetry (ECG)
- [ ] Plethysmography (SpO2)
- [ ] Continuous Core Body Temperature

51

What other secondary brain injury patterns or pathologies might you detect, predict, or gain clinically-relevant insight into by using multimodality neuromonitoring data?

Minimum Necessary Technology: Devices & Measurements

For each question, consider a hypothetical patient who requires the MOST comprehensive multimodality neuromonitoring available to you. Please do not consider specific brands or types of devices, rather focus on the measurement parameter itself.

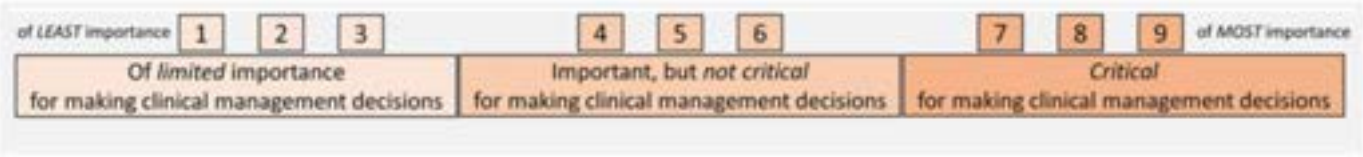
How important are each of the following measurements to your clinical decision-making?

If a measurement modality is important only in conjunction with another measurement, BOTH should be rated as important. For example, if you feel cerebral autoregulation is extremely important and you measure it using rSO2, then rate both as extremely important even if you do not use rSO2 for anything else.

If you have no experience with using a particular measurement modality in clinical practice, simply answer to the best of your ability based on your experience and knowledge.

52

Intracranial Pressure (ICP)



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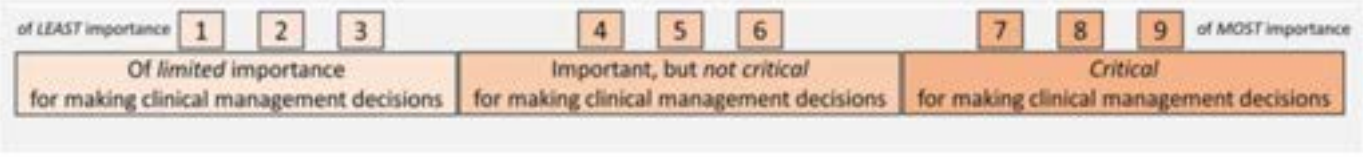
53

Cardiac Output (including associated measures of intravascular volume)



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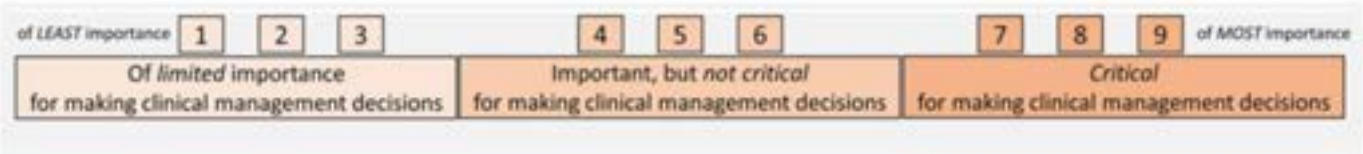
54

Cerebral Perfusion Pressure (CPP)



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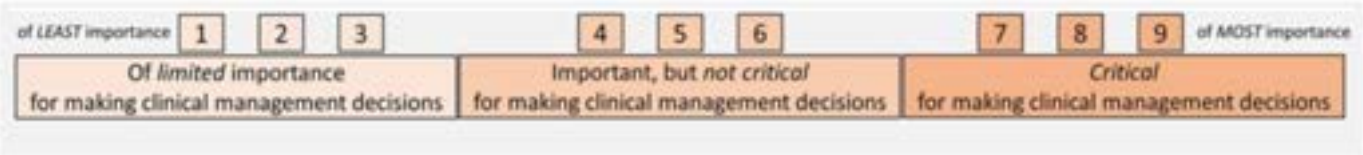
55

Optimal Cerebral Perfusion Pressure (CPPopt)



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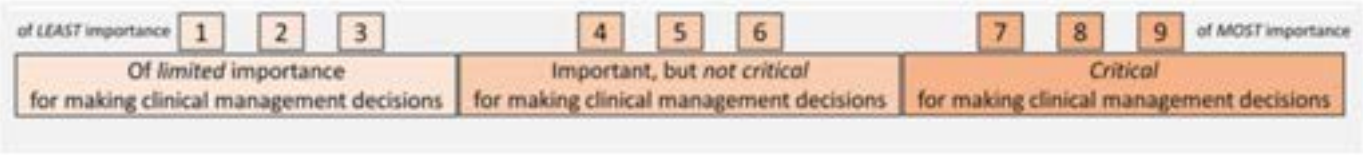
56

Cerebrovascular Autoregulation



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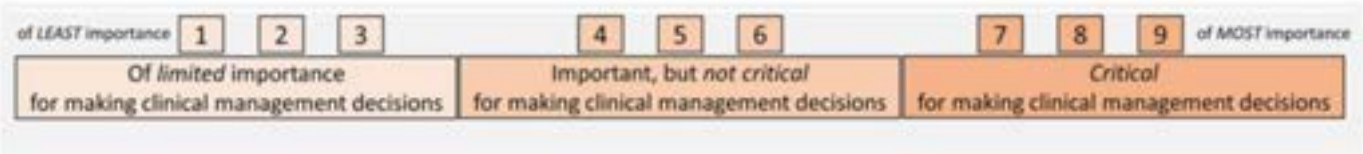
57

End-Tidal Capnography (ETCO2)



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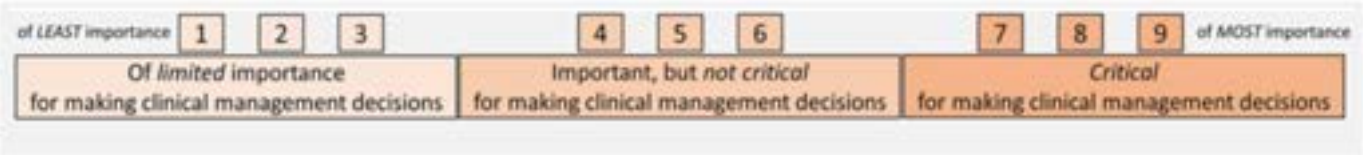
58

Brain Tissue Oxygen (PbtO2 or PtiO2)



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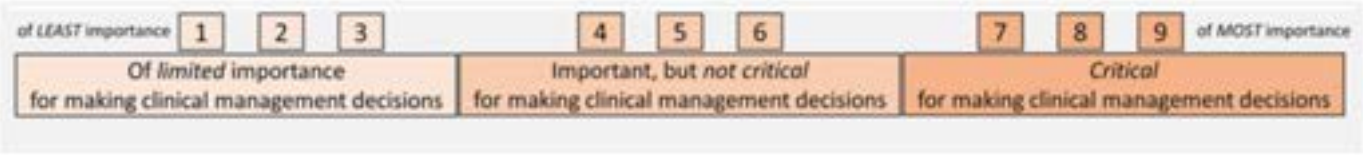
59

Jugular Venous Oxygen (SjvO2)



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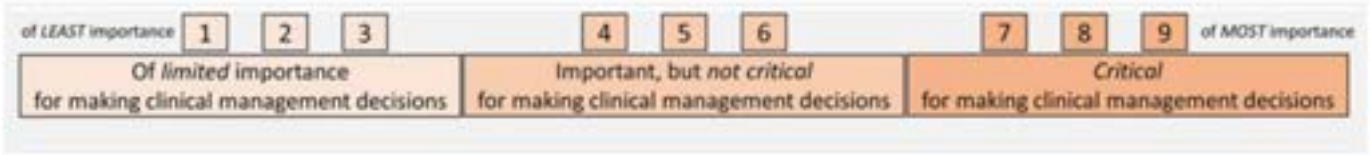
60

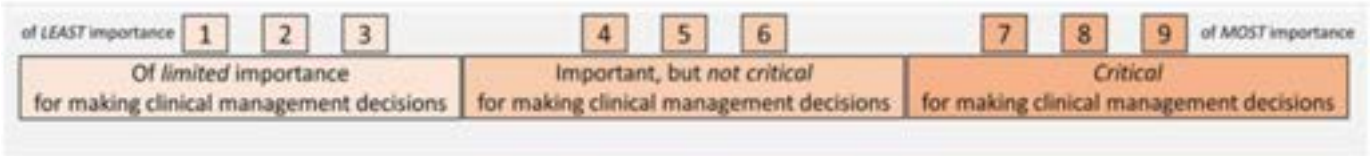
Regional Oxygen Saturation (rSO2) using Near-Infrared Spectroscopy (NIRES) or other optical imaging technology



1 2 3 4 5 6 7 8 9

61

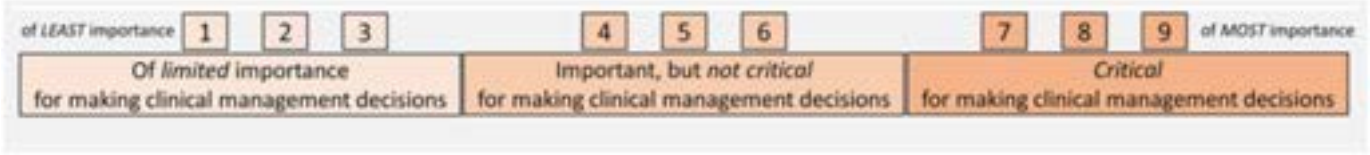
Regional Cerebral Blood Flow (rCBF)



1 2 3 4 5 6 7 8 9

62

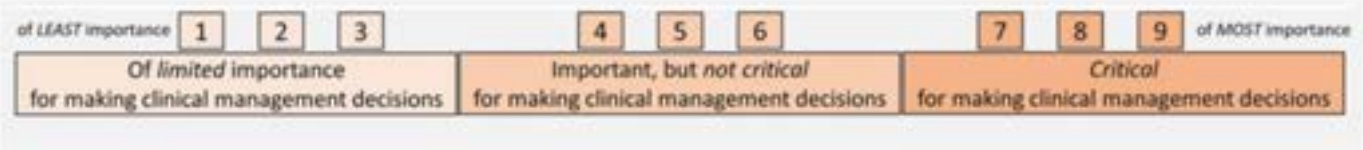
Brain Temperature



1 2 3 4 5 6 7 8 9

63

Brain Water Constant (K)



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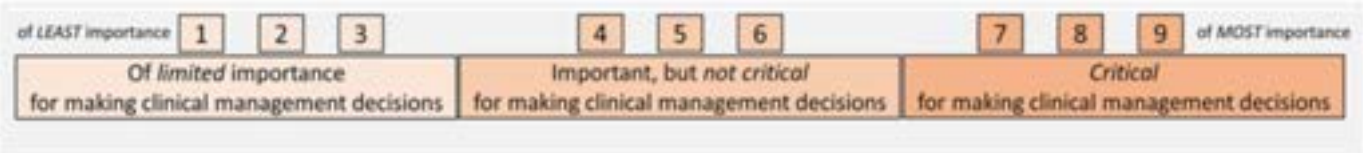
64

Cerebral Microdialysis: Lactate & Pyruvate



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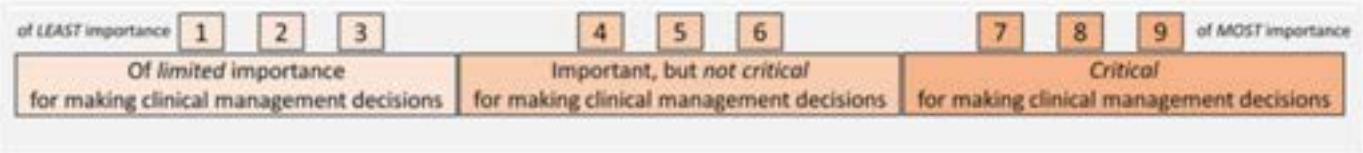
65

Cerebral Microdialysis: Brain Tissue Glucose



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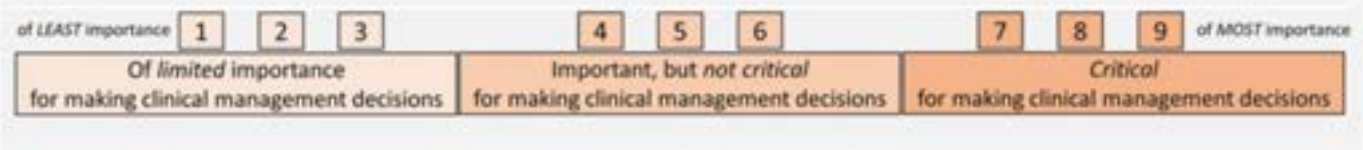
66

Cerebral Microdialysis: Glutamate



1 2 3 4 5 6 7 8 9

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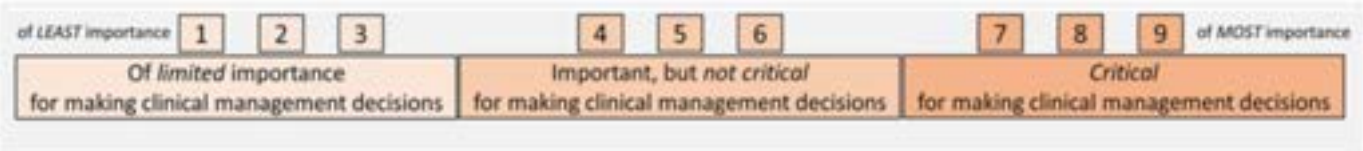
67

Cerebral Microdialysis: Glycerol



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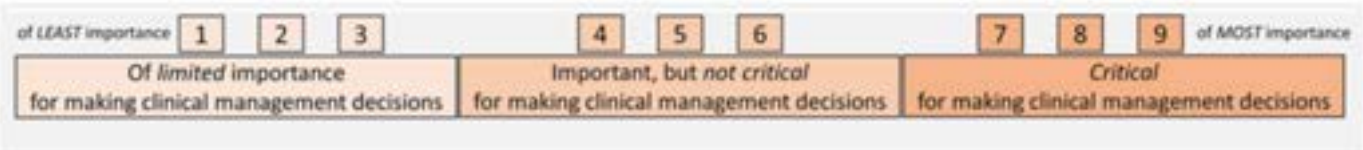
68

Continuous Scalp EEG



1 2 3 4 5 6 7 8 9

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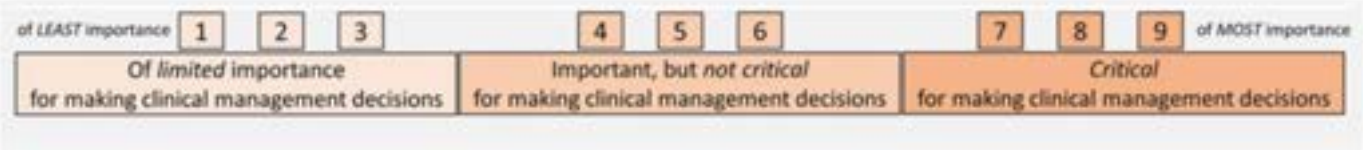
69

Electrocorticography: Single-wire or Depth Electrode



1 2 3 4 5 6 7 8 9

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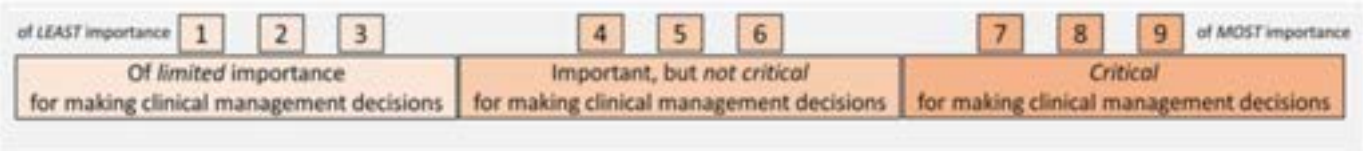
70

Electrocorticography: Strip Electrode



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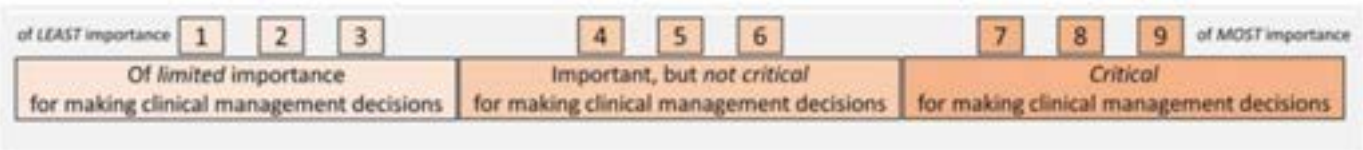
71

Full-band (DC or near-DC) EEG Recordings



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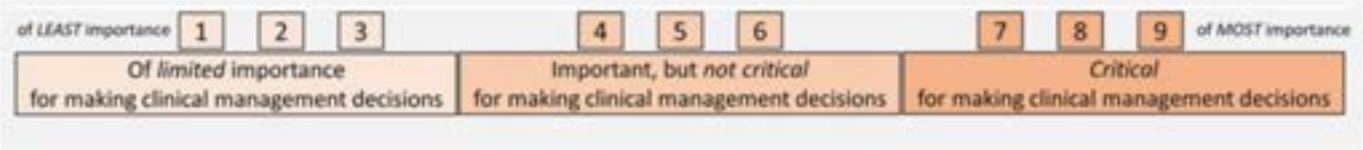
72

Quantitative EEG



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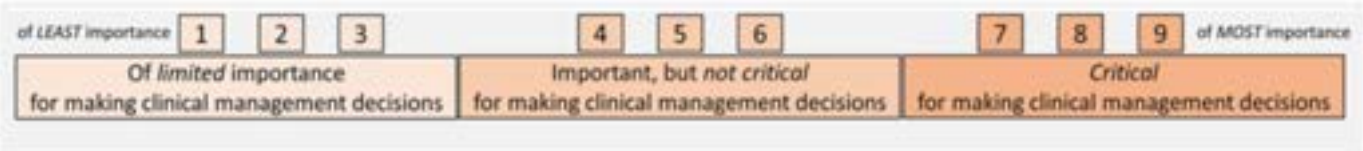
73

Processed EEG Indices of Anesthesia/Sedation Depth



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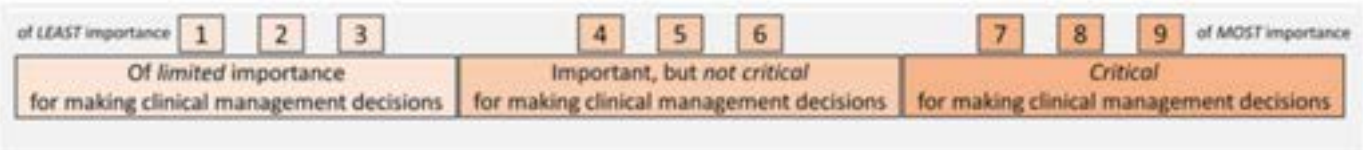
74

Quantitative Pupillometry



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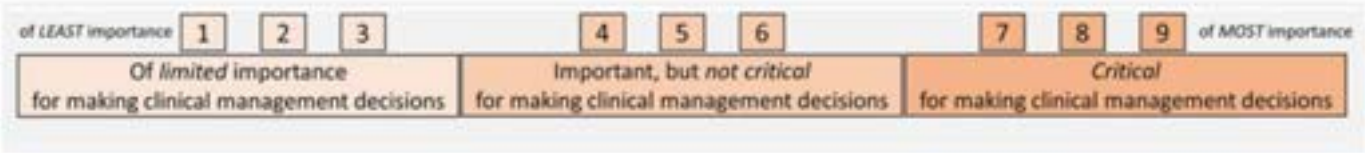
75

Extended-Duration (> 30 min) or Frequent (> 1 daily) Transcranial Doppler Ultrasonography



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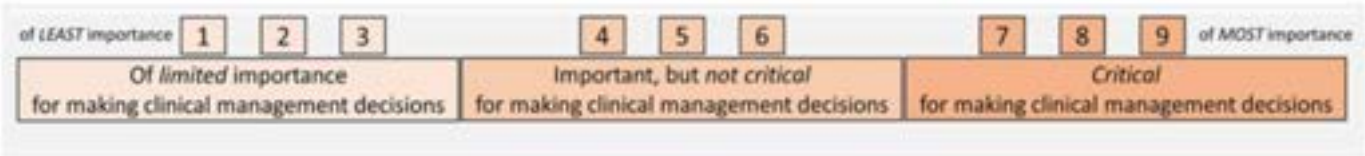
76

Autonomic Function (e.g. heart rate variability)



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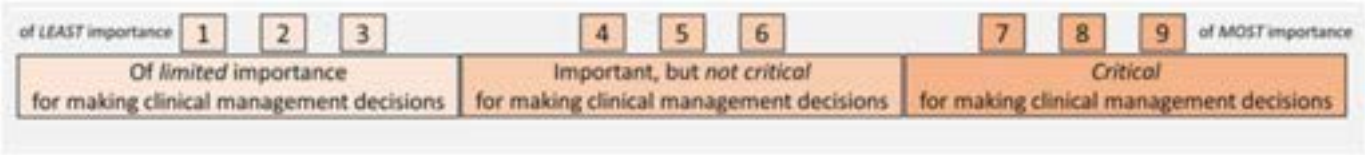
77

Arterial Blood Pressure (ABP)



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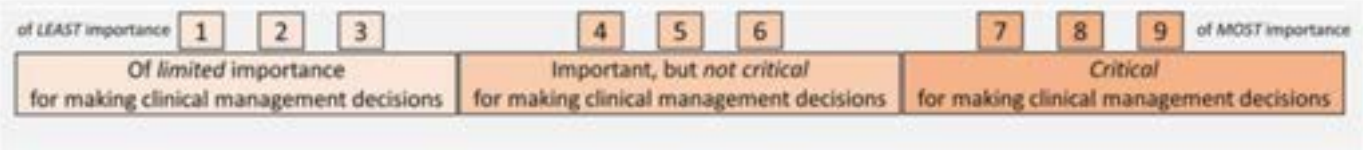
78

Cardiac Telemetry (ECG)



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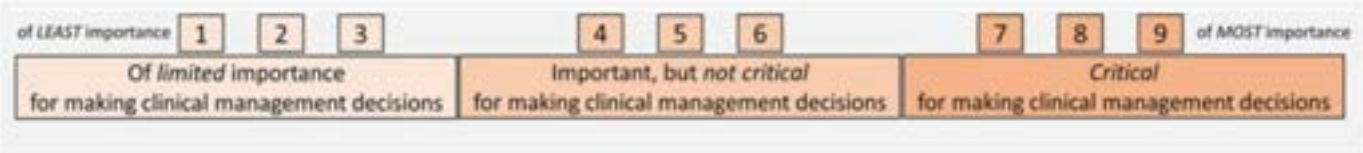
79

Continuous Core Body Temperature



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80

What other neuromonitoring measurements do you consider to be important in clinical decision-making? Please be specific.

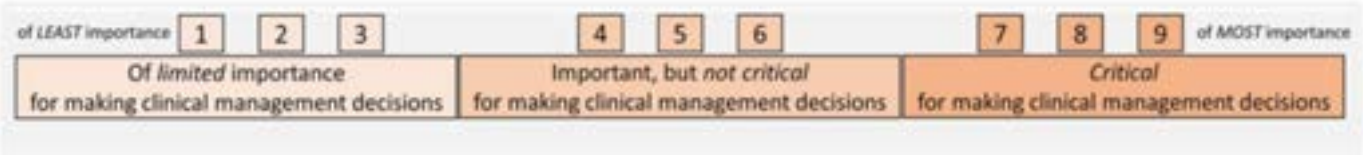
Minimum Necessary Technology: Access

How important are each of the following to the use of neuromonitoring data to make care decisions?

If you have no personal experience accessing neuromonitoring data as described below, answer to the best of your abilities based on your experience and knowledge.

81

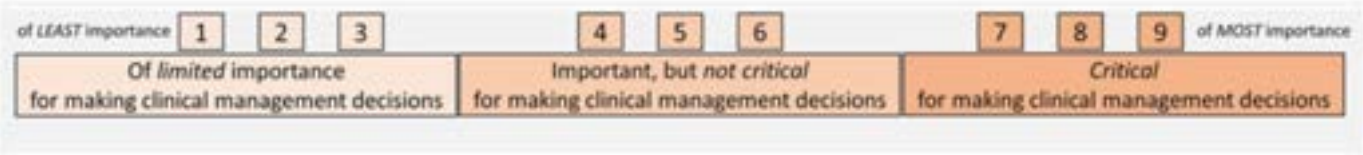
Bedside visualization or display of a single, current (live) measurement value, e.g. a single numeric value displayed on a device at that moment in time visible in a patient care area



1 2 3 4 5 6 7 8 9

82

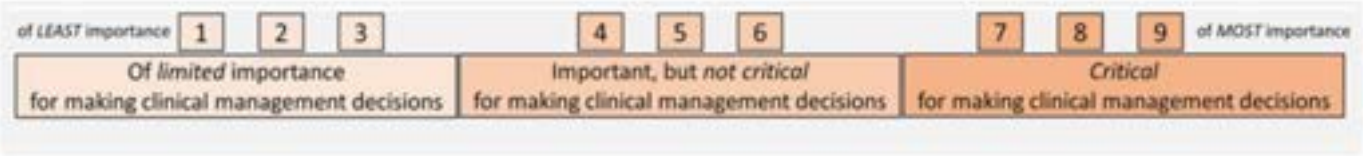
Bedside visualization or display of single measurement trended over time, e.g. a graph of a time-series displayed on a device visible in a patient care area



1 2 3 4 5 6 7 8 9

83

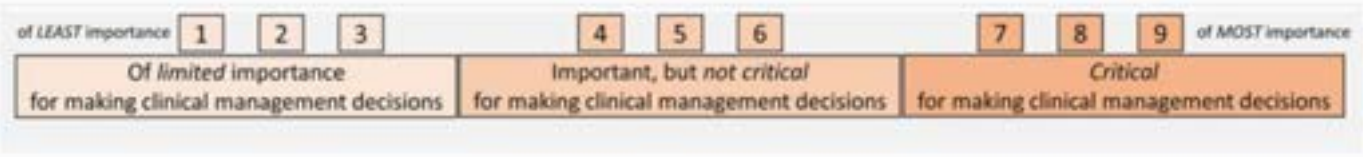
Bedside visualization or display of multiple, current (live) measurement values together on the same screen, e.g. multiple numeric measurement values from different devices displayed on the same screen and visible in a patient care area



1 2 3 4 5 6 7 8 9

84

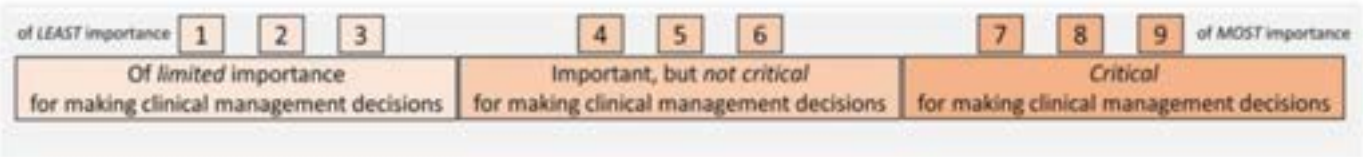
Bedside visualization or display of multiple measurements trended over time and aligned on the same screen, e.g. a graph of several time-series from different devices displayed on the same screen and visible in a patient care area



1 2 3 4 5 6 7 8 9

85

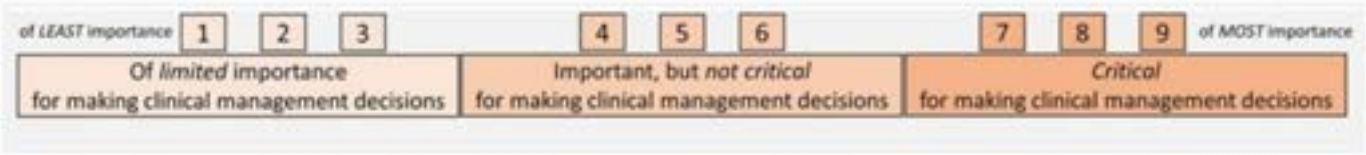
Access to data with high temporal resolution (1 or more data points every minute) including clinically-standard data such as heart rate, arterial blood pressure in addition to neuromonitoring-specific data



1 2 3 4 5 6 7 8 9

86

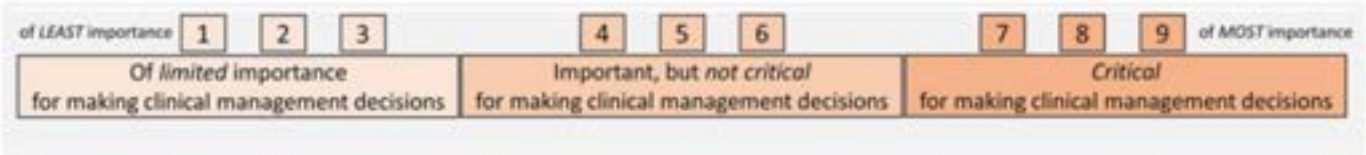
Access to data at waveform resolution, such as ECG waveforms, arterial blood pressure or intracranial pressure waveforms, or EEG signals



1 2 3 4 5 6 7 8 9

87

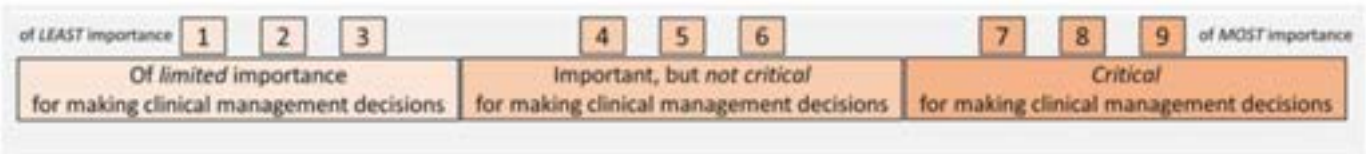
Electronic Health Record capture of single measurement values, e.g. within flowsheet rows or tables



1 2 3 4 5 6 7 8 9

88

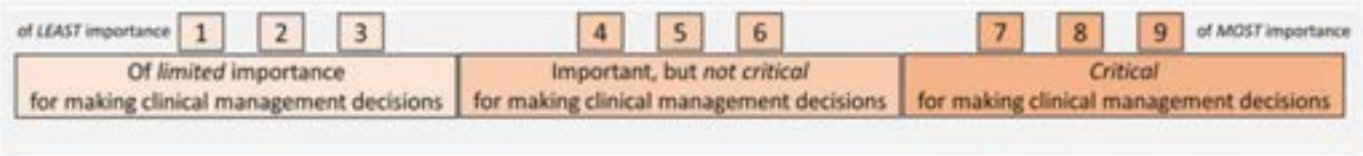
Electronic Health Record display (in a table or graph) of multiple different measurement values together on a single panel, tab, or screen



1 2 3 4 5 6 7 8 9

89

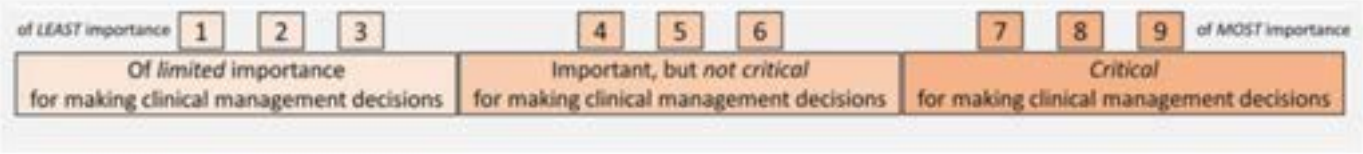
Ability to manipulate data visualization or display AT BEDSIDE, e.g. zooming in or out (time scaling), scrolling back and forth in time, or selecting which neuromonitoring measurements to display



1 2 3 4 5 6 7 8 9

90

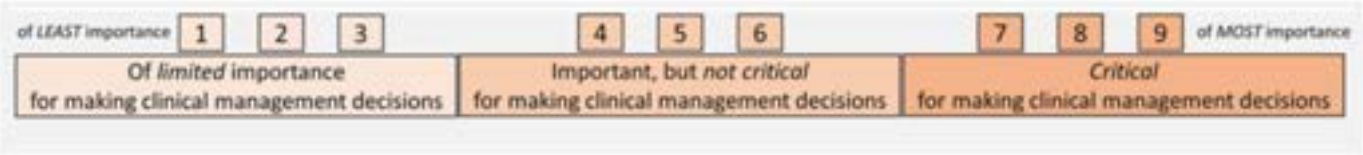
Ability to annotate neuromonitoring data AT BEDSIDE to indicate clinical events or other contextural data



1 2 3 4 5 6 7 8 9

91

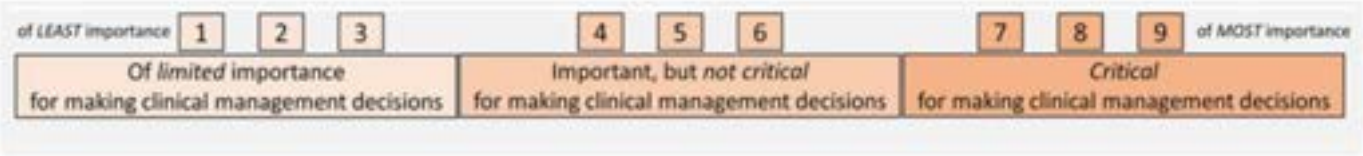
Ability to display neuromonitoring data AT BEDSIDE linked with annotations to indicate clinical events or other contextural data



1 2 3 4 5 6 7 8 9

92

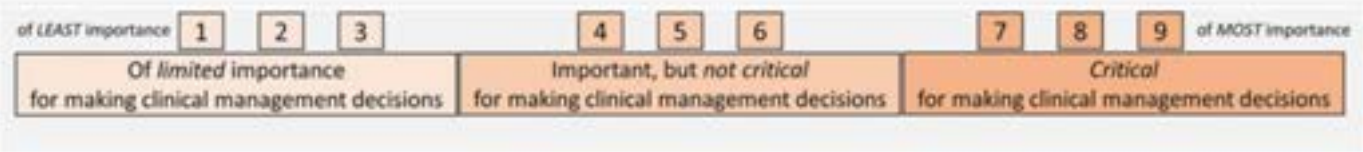
Ability to display neuromonitoring data AT BEDSIDE linked with Electronic Health Record information, e.g. laboratory values or medication administration information



1 2 3 4 5 6 7 8 9

93

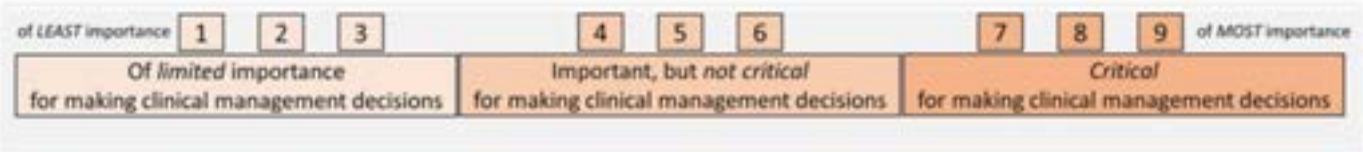
Ability to visualize or display neuromonitoring data in real-time REMOTELY (from a separate reading room or from home)



1 2 3 4 5 6 7 8 9

94

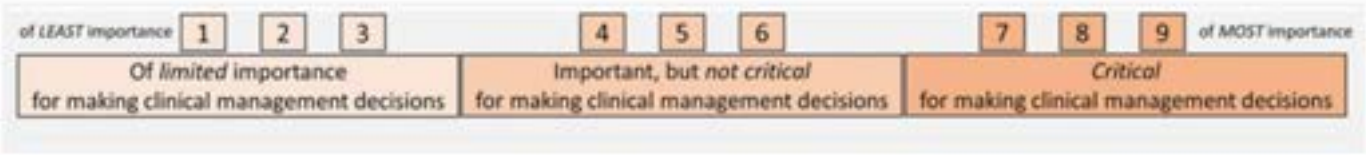
Ability to manipulate and review displayed neuromonitoring data in real-time REMOTELY (from a separate reading room or from home), e.g. choosing specific neuromonitoring measurements to display or zooming in or out of the data



1 2 3 4 5 6 7 8 9

95

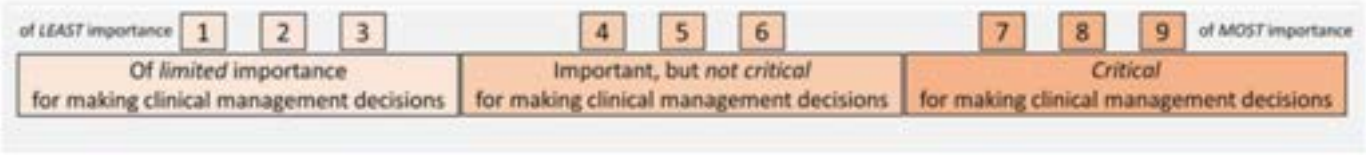
Ability to annotate neuromonitoring data REMOTELY to indicate clinical events or other contextural data



1 2 3 4 5 6 7 8 9

96

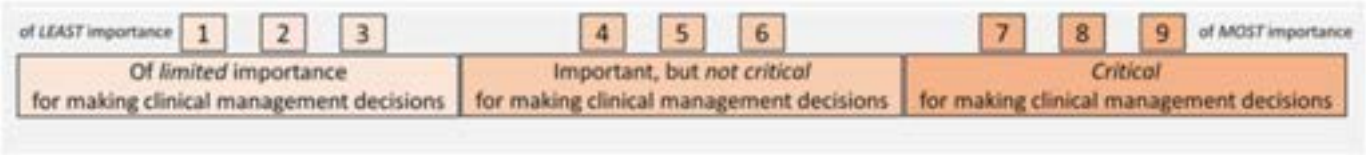
Ability to display neuromonitoring data REMOTELY linked with bedside annotations that indicate clinical events or other contextural data



1 2 3 4 5 6 7 8 9

97

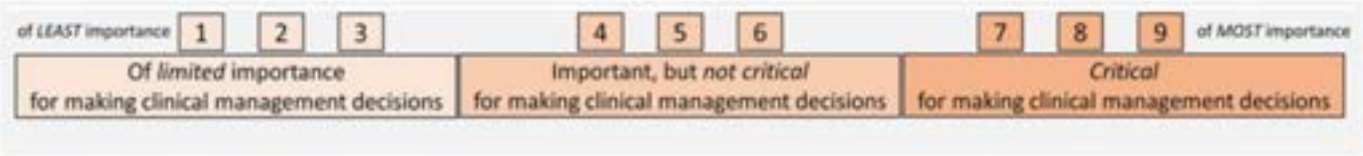
Ability to display neuromonitoring data REMOTELY linked with Electronic Health Record information, e.g. laboratory values or medication administration information



1 2 3 4 5 6 7 8 9

98

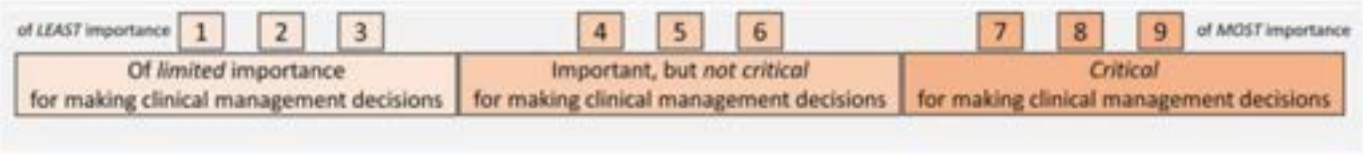
Ability to access neuromonitoring data for use in other software packages (e.g. Excel or R) by downloading from a hardware interface (e.g. bedside download of data through a USB drive)



1 2 3 4 5 6 7 8 9

99

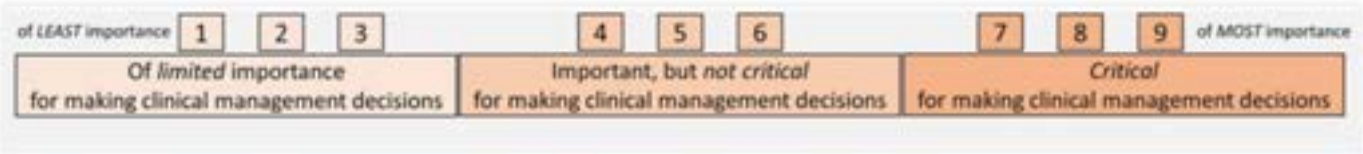
Ability to access neuromonitoring data for use in other software packages (e.g. Excel or R) through software or server-based interface, e.g. data is accessible from a server



1 2 3 4 5 6 7 8 9

100

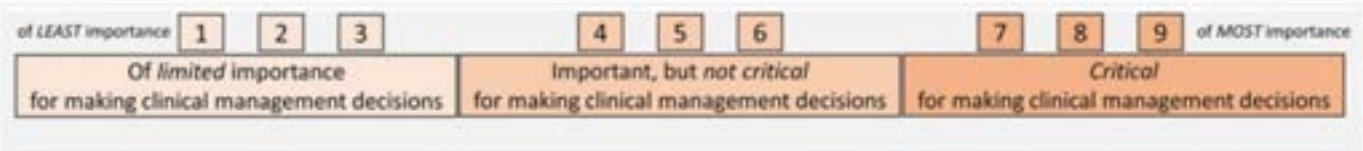
Ability to set alarms or thresholds to alert staff AT BEDSIDE, e.g. via flashing colors or alarm sounds



1 2 3 4 5 6 7 8 9

101

Ability to set alarms or thresholds to alert staff REMOTELY, e.g. through push notifications or email



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102

What other technologies or accessibility options do you find important in clinical decision-making? Please be specific.

Minimum Necessary Work: Open-Ended Questions

103

What criterion or criteria would you use to distinguish 'multimodality neuromonitoring' from the work of critical care, the work of interpreting continuous video-EEG, or general clinical duties? What, if anything, makes 'multimodality neuromonitoring' distinct?

104

In your view, how can multimodality neuromonitoring data best be operationalized in clinical practice on a day-to-day basis right now? How can multimodality neuromonitoring best be made usable or actionable at your institution?

105

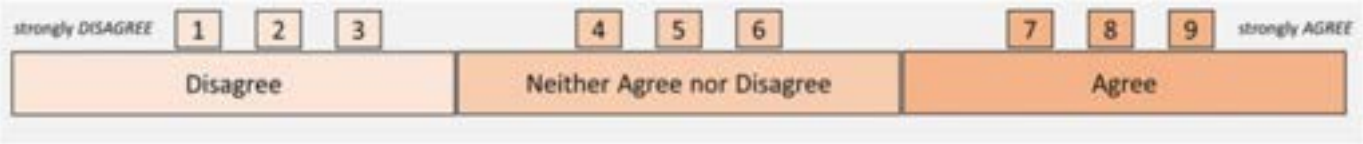
Imaginge you are talking care of a patient with severe brain injury. Just before walking into rounds, you are provided a summary report of your patient's neuromonitoring data. What information would you find helpful from such a report?

Minimum Necessary Work: Agree or Disagree

For the following questions, indiate the level of agreement about the following statements.

106

I feel that most intensivists staffing an ICU and caring for patients with brain injuries are able to adequately INTEGRATE AND INTERPRET multimodality neuromonitoring data as part of daily clinical care in order to make management decisions.



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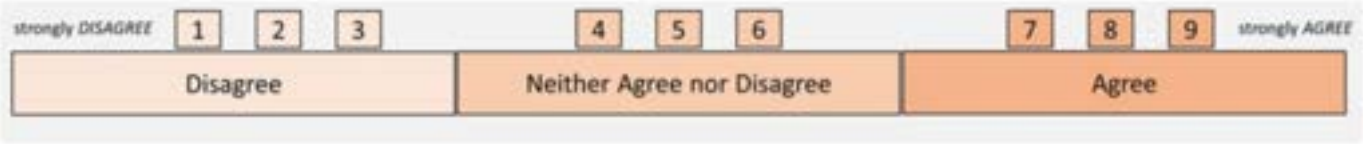
107

I feel that most intensivists staffing an ICU and caring for patients with brain injuries have adequate TIME to fully review all available multimodality neuromonitoring data as part of daily clinical care.



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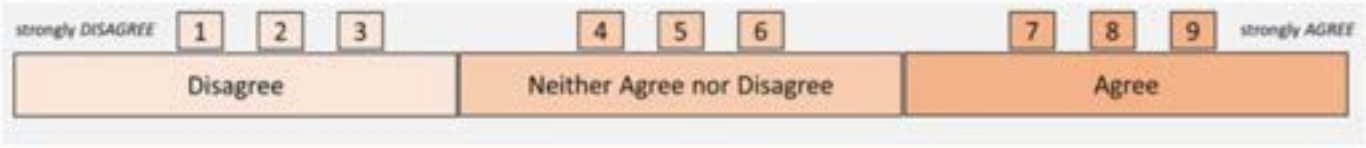
108

I feel that most intensivists staffing an ICU and caring for patients with brain injuries have all the necessary TECHNOLOGY to integrate and interpret multimodality neuromonitoring data as part of daily clinical care.



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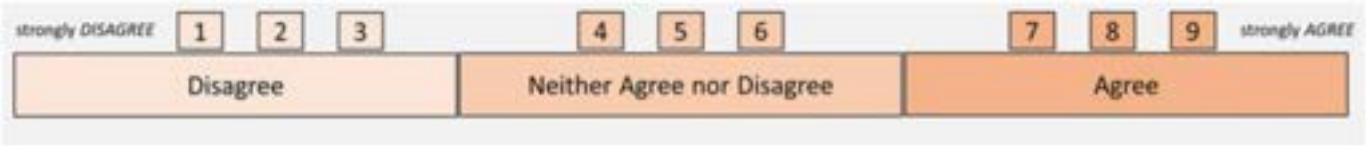
109

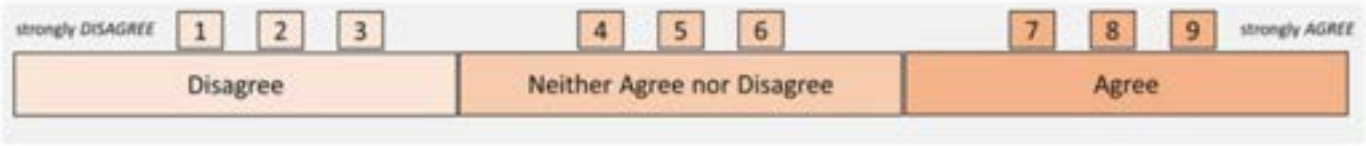
I feel that most intensivists staffing an ICU and caring for patients with brain injuries have TECHNICAL KNOWLEDGE sufficient to troubleshoot device errors and to identify artifactual or erroneous multimodality neuromonitoring data.



1 2 3 4 5 6 7 8 9

110

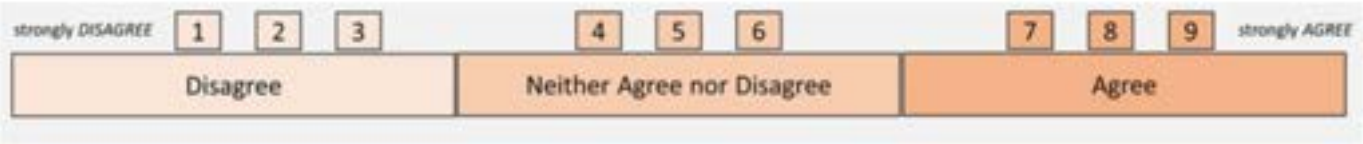
I feel that most intensivists staffing an ICU and caring for patients with brain injuries have CLINCAL KNOWLEDGE of brain physiology sufficient to use multimodality neuromonitoring data in making clinical decisions as part of daily clinical care.



1 2 3 4 5 6 7 8 9

111

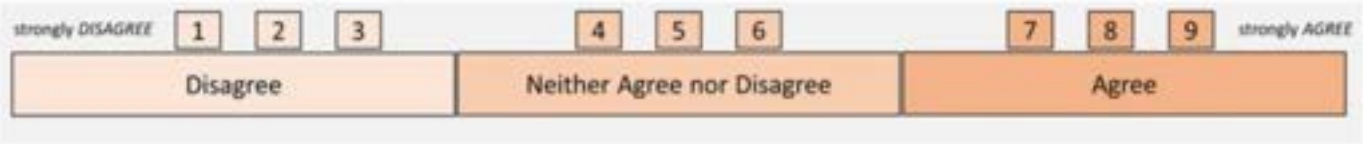
I feel most intensivists staffing an ICU and caring for patients with brain injuries would find regularly written reports summarizing multimodality neuromonitoring data and providing clinical interpretation/correlation to be helpful in making clinical decisions as part of daily clinical care.



1 2 3 4 5 6 7 8 9

112

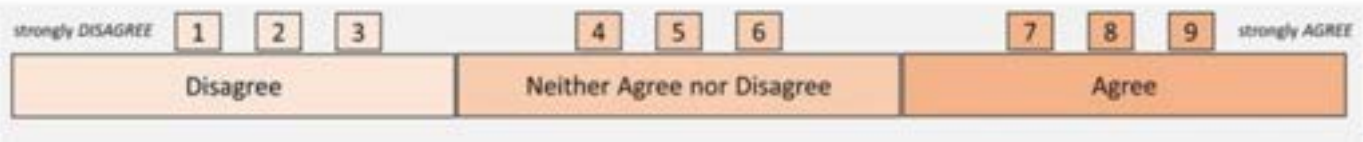
I feel that the INTEGRATION AND INTERPRETATION of multimodality neuromonitoring requires access to raw data for data manipulation outside of the devices on which data is measured, e.g. for pre-processing/cleaning, aggregation, integration with other data, computational analytics, and/or statistical analysis.



1 2 3 4 5 6 7 8 9

113

I feel that the INTEGRATION AND INTERPRETATION of multimodality neuromonitoring data requires review of a variety of time-scales - from hours to days of data - in order to make clinically-meaningful inferences from the information.



1 2 3 4 5 6 7 8 9

114

Please enter any additional comments about the work required for multimodality neuromonitoring.

Training Standards: Open-Ended Questions

115

What training background is best suited to understand and make clinically-meaningful inferences from multimodality neuromonitoring data?

116

What core concepts are required to understand and make clinically-meaningful inferences from multimodality neuromonitoring data?

117

What educational format is best to train clinicians to understand and make clinically-meaningful inferences from multimodality neuromonitoring data?

Training Standards: Agree or Disagree

For the following questions, indiate the level of agreement about the following statements.

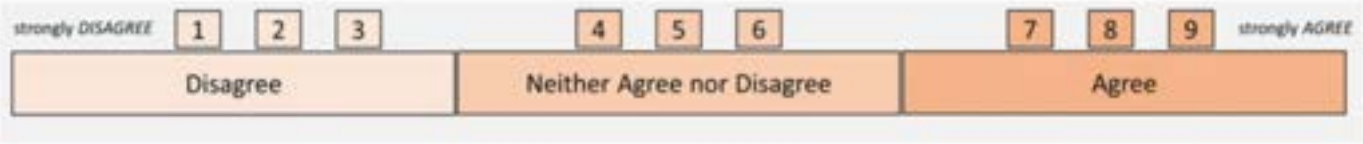
118

I feel that specific training or expertise is required to best understand and interpret multimodality neuromonitoring information.

1 2 3 4 5 6 7 8 9

119

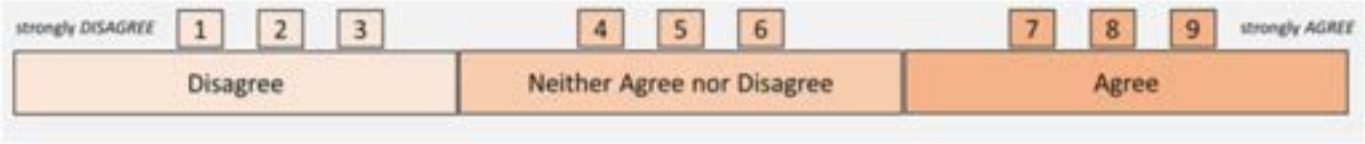
I feel that clinical training programs in the neurological specialties provide a knowledge base that best allows clinicians to understand and interpret multimodality neuromonitoring information.



1 2 3 4 5 6 7 8 9

120

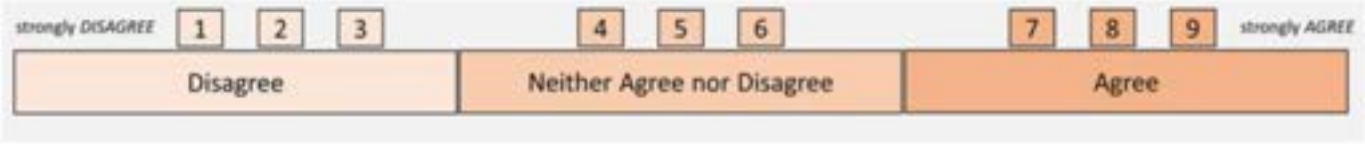
I feel that clinical training programs in intensive care provide a knowledge base that best allows clinicians to understand and interpret multimodality neuromonitoring information.



1 2 3 4 5 6 7 8 9

121

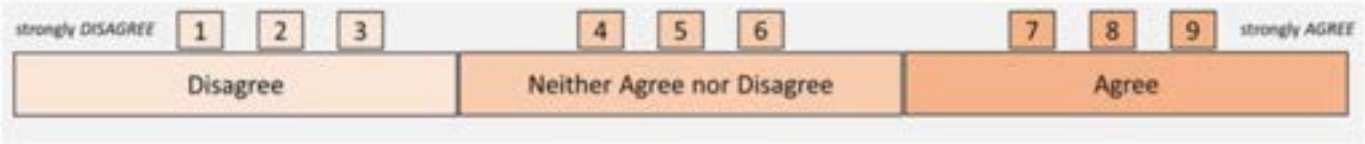
I feel that ALL clinical training programs for practitioners who will be taking care of brain injured patients should provide education dedicated specifically to understanding the technical and clinical aspects of multimodality neuromonitoring.



1 2 3 4 5 6 7 8 9

122

I feel that ONLY clinical training programs at centers that regularly use multimodality neuromonitoring should provide education dedicated specifically to understanding the technical and clinical aspects of multimodality neuromonitoring.



1 2 3 4 5 6 7 8 9

123

Please enter any additional comments about multimodality neuromonitoring training standards.

The Practice of Clinical Multimodality Neuromonitoring: an eDelphi Consensus Statement

* Required

Problem & Rationale

This survey serves as **Round 2** of an eDelphi process designed to provide consensus for areas of uncertainty with goal of providing standards by which multimodality neuromonitoring may be distinguished as a unique diagnostic specialty.

Round 2 will be used to quantify agreement and consensus and does not include open-ended questions. All responses from Round 1 were reviewed and incorporated as new questions which were added to appropriate sections throughout the survey. For previously answered questions, summary statistics are provided from Round 1 to incorporate into your responses in this Round.

By way of reminder, 'neuromonitoring' refers to the use of any frequent (ideally *continuously*) measure of brain physiology that can be performed at the bedside with a focus on detecting clinically-important events in real-time. This is distinct from 'neurodiagnostic' technologies such as radiological tests (CT, MRI) or tests ordered only infrequently or as-needed, such as somatosensory evoked potentials or serum-based biomarkers.

'Multimodality neuromonitoring' refers to the use of *more than one data source* to provide a comprehensive assessment of the brain. This usually implies a higher level of complexity reserved for selected at-risk patients, typically in an ICU setting with limitations in neurological exam, such as coma.

Respondent Information

The eDelphi process is strictly anonymous and no identifying information should be shared.

You will find the same questions answered during Round 1 which will serve to compare both Rounds for consistency.

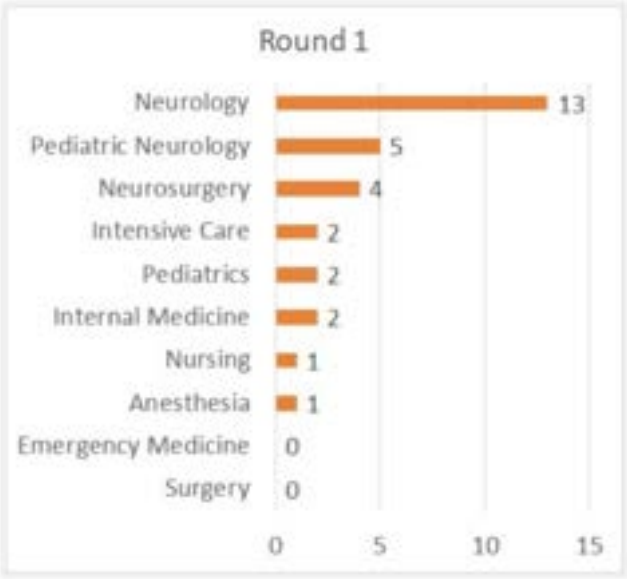
1

Please indicate if you previously completed Round 1: *

- ○ No
- ○ Yes

2

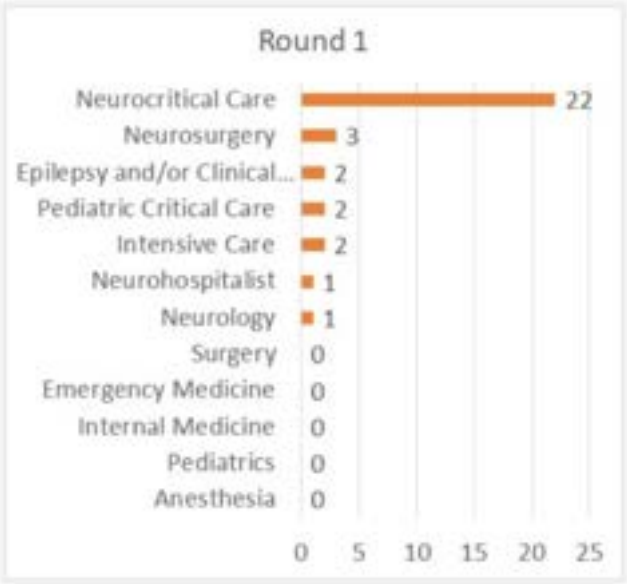
What is your training background?



- ○ Neurology
- ○ Pediatric Neurology
- ○ Neurosurgery
- ○ Internal Medicine
- ○ Pediatrics
- ○ Anesthesia
- ○ Surgery
- ○ Emergency Medicine
- ○ Nursing
- ○ Other

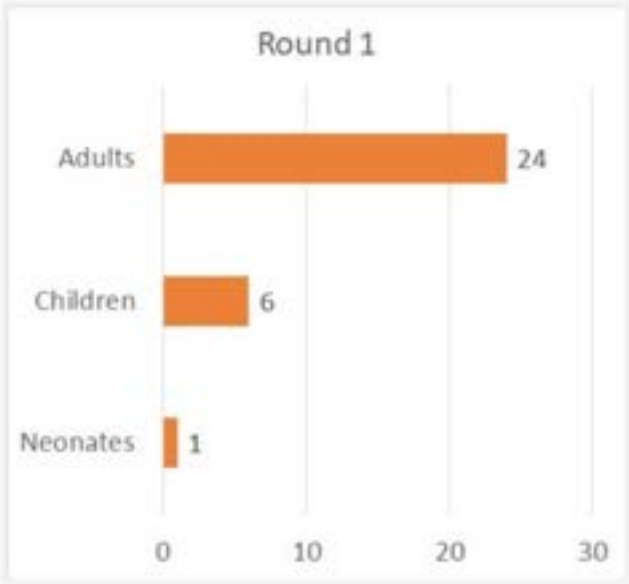
3

Which is your current primary practice? (select all that apply)



- [ ] Neurocritical Care
- [ ] Intensive Care
- [ ] Anesthesia
- [ ] Pediatric Critical Care
- [ ] Pediatrics
- [ ] Neurology
- [ ] Epilepsy and/or Clinical Neurophysiology
- [ ] Internal Medicine
- [ ] Neurosurgery
- [ ] Emergency Medicine
- [ ] Surgery
- [ ] Other

4

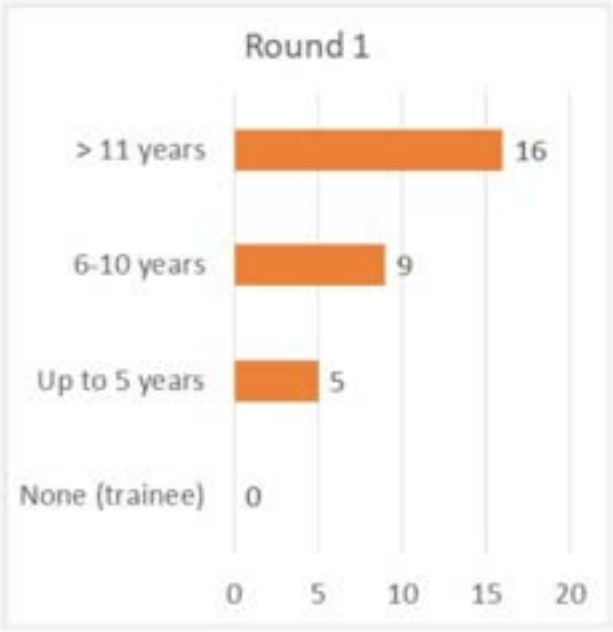


Which population do you primarily care for? (select all that apply)

- [ ] Adults
- [ ] Children
- [ ] Neonates
- [ ] Other

5

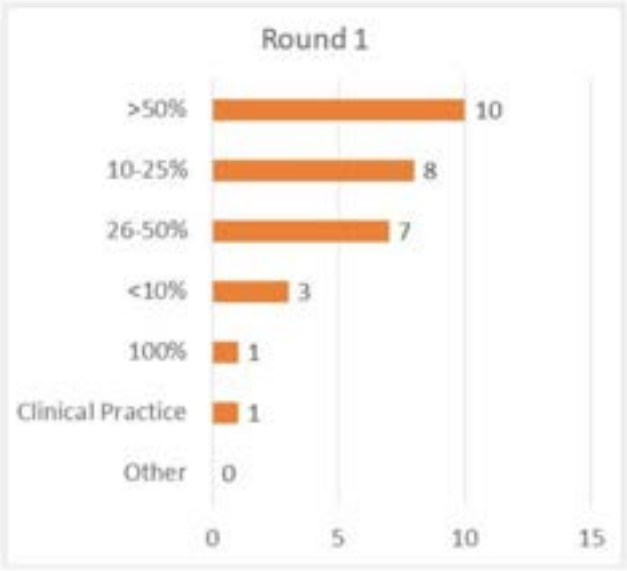
How many years have you been in independent practice?



- ◯ None (trainee)
- ◯ up to 5 years
- ◯ 6-10 years
- ◯ > 11 years

6

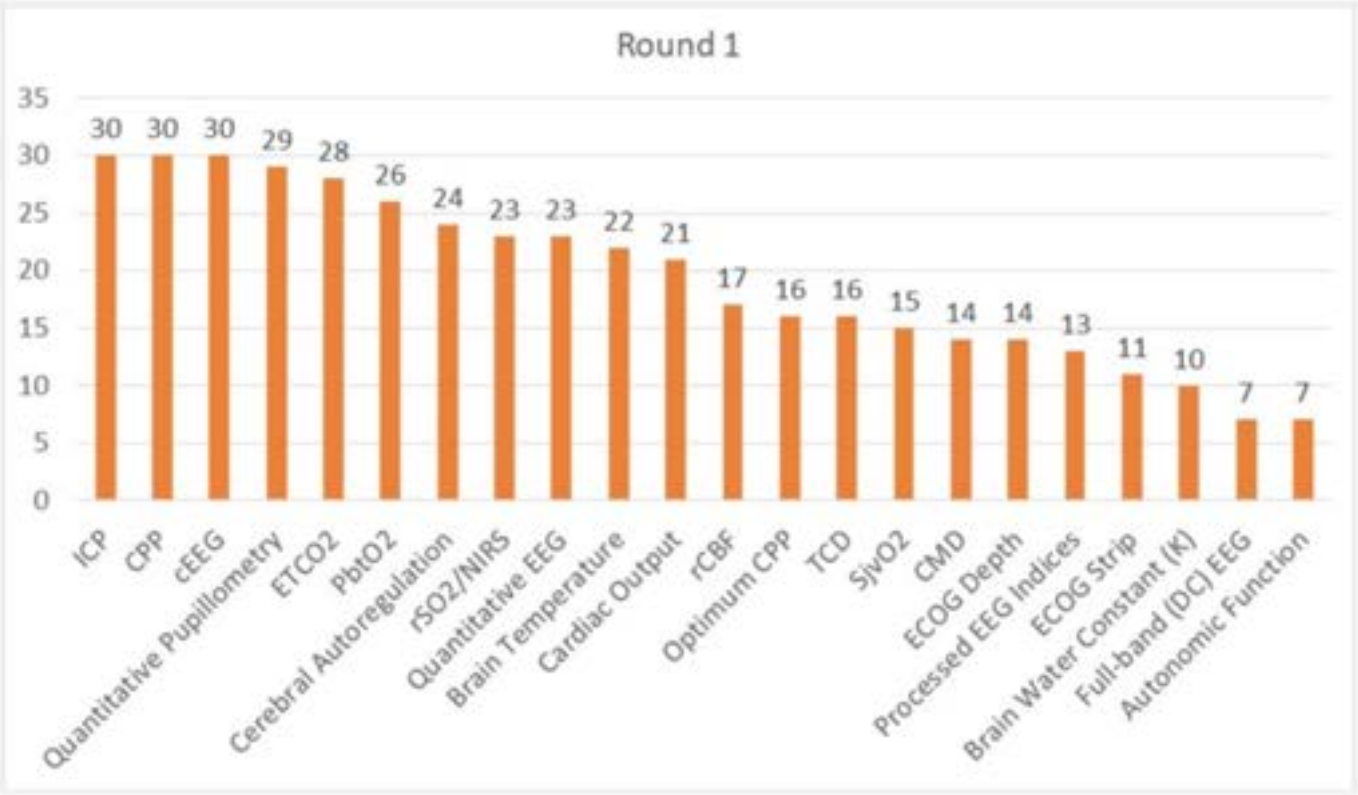
What is your academic research time allocation (%)?



- NA; I work in a community/private practice setting
- 100% of my time is dedicated to clinical duties
- <10% of my time is dedicated research time
- 10-25% of my time dedicated research time
- 26-50% of my time is dedicated research time
- >50% of my time is protected for research
- Other

Please select each of the physiologic measurement modalities below that you personally have used at some point in your career to provide or recommend care for patients:

N.B. This question assumes the routine use of clinically-standard non-invasive and arterial blood pressure, cardiac telemetry, peripheral oxygen saturation , and core body temperature monitoring



- [ ] Intracranial Pressure (ICP)
- [ ] Cardiac Output (including associated measures of intravascular volume)
- [ ] Cerebral Perfusion Pressure (CPP)
- [ ] Optimal Cerebral Perfusion Pressure (CPPopt)
- [ ] Cerebral Autoregulation
- [ ] End-Tidal Capnography (ETCO2)
- [ ] Brain Tissue Oxygen (PbtO2 or PtiO2)
- [ ] Jugular Venous Oxygen (SjvO2)
- [ ] Regional Oxygen Saturation (rSO2) using Near-Infrared Spectroscopy (NIRS) or other optical imaging technology
- [ ] Regional Cerebral Blood Flow (rCBF)

- [ ] Brain Temperature
- [ ] Brain Water Constant (K)
- [ ] Cerebral Microdialysis
- [ ] Continuous Scalp EEG
- [ ] Electrocorticography: Single-wire or Depth Electrode
- [ ] Electrocorticography: Strip Electrode
- [ ] Full-band (DC or near-DC) EEG Recordings
- [ ] Quantitative EEG
- [ ] Processed EEG Indices of Anesthesia/Sedation Depth
- [ ] Quantitative Pupillometry
- [ ] Extended-Duration (> 30 min) or Frequent (> 1 daily) Transcranial Doppler Ultrasonography (TCD)
- [ ] Autonomic Function (e.g. heart rate variability)

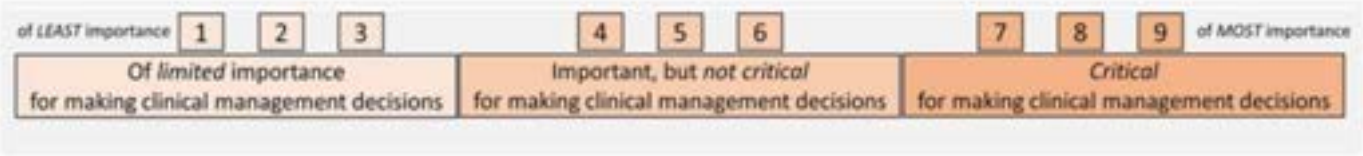
Contexts of Use: Clinical Considerations

Context of use is defined as the users, tasks, equipment, and the physical and social environments in which a system or service is used (ISO 9241-11:1998, 3.5, modified). In this case, we refer to the medical environment, e.g. the type of problem that a patient may have for which multimodality neuromonitoring might be useful or helpful.

8

How important is level of consciousness when determining the clinical utility of mulitmodality neuromonitoring for a patient?

Round 1: Median [IQR] 8 [7-9]

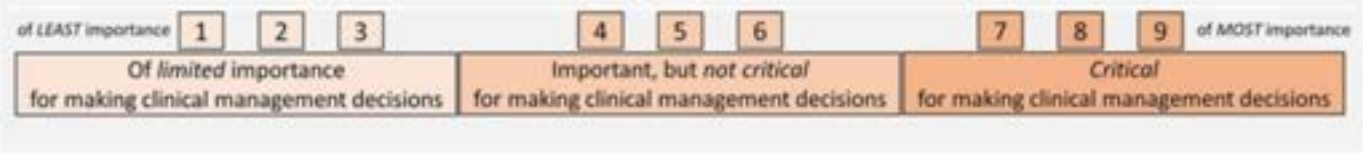


1 2 3 4 5 6 7 8 9

9

New Question

How important are confounding factors that may cloud the neurological examination when determining the clinical utility of multimodality neuromonitoring for a patient?

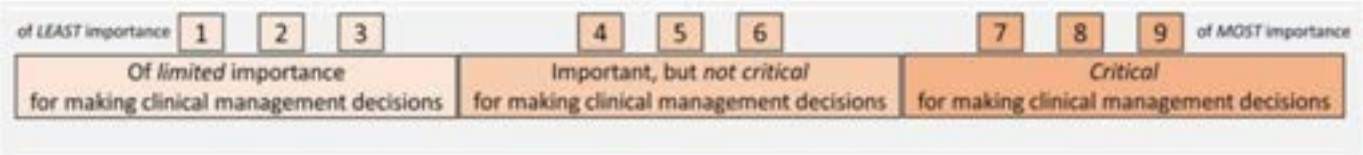


1 2 3 4 5 6 7 8 9

10

How important is the underlying disease or diagnosis when determining the clinical utility of multimodality neuromonitoring for a patient?

Round 1: Median [IQR] 7 [7-8]

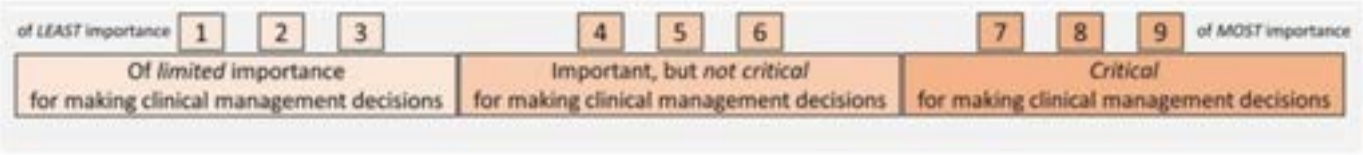


1 2 3 4 5 6 7 8 9

11

New Question

How important is the presence of additional organ dysfunction (e.g. stress cardiomyopathy or acute respiratory distress syndrome [ARDS]) when determining the clinical utility of multimodality neuromonitoring for a patient?

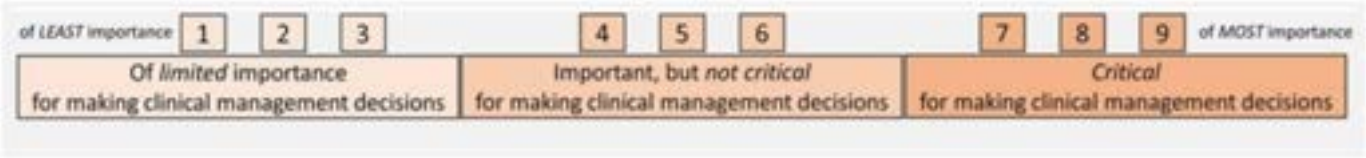


1 2 3 4 5 6 7 8 9

12

How important is the potential risk for secondary brain injuries or secondary neurodeterioration when determining the clinical utility of multimodality neuromonitoring for a patient?

Round 1: Median [IQR] 8.5 [8-9]

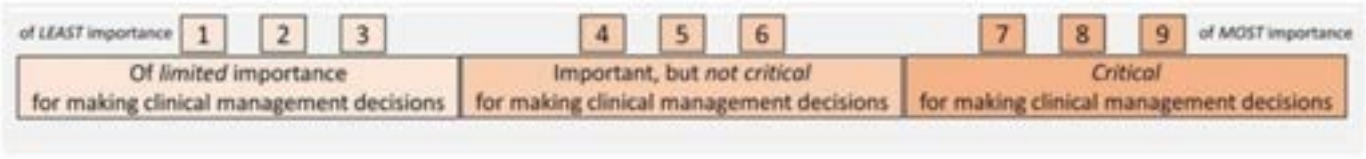


1 2 3 4 5 6 7 8 9

13

New Question

How important is a desire to understand the pathophysiology underlying brain dysfunction (e.g. diffuse vs focal injury processes) when determining the clinical utility of multimodality neuromonitoring?

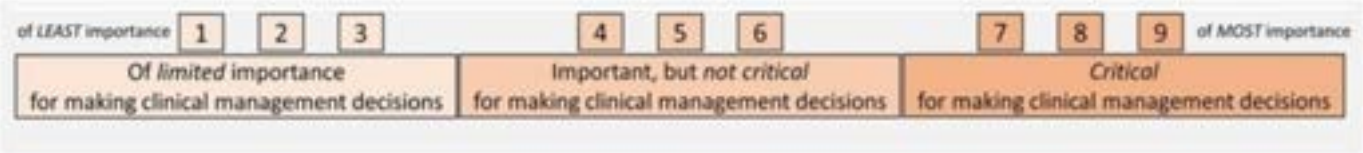


1 2 3 4 5 6 7 8 9

14

New Question

How important is the time point within a specific disease course (e.g. the number of days following an injury) when determining the clinical utility of multimodality neuromonitoring?



1 2 3 4 5 6 7 8 9

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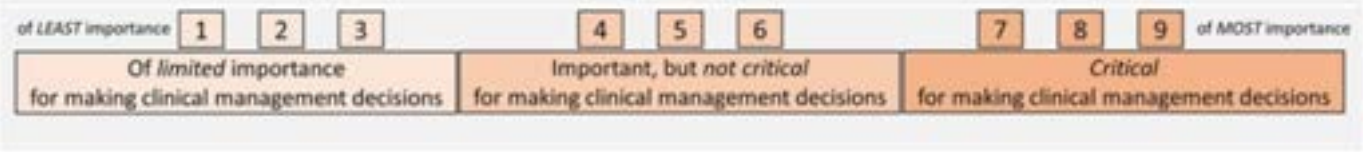
15

How important is the potential for harm related to placement of invasive neuromonitoring devices or neuromonitoring devices with more than minimal risk relative to their benefit when determining the clinical utility of multimodality neuromonitoring for a patient?

Round 1: Median [IQR] 7 [6-9]



1 2 3 4 5 6 7 8 9

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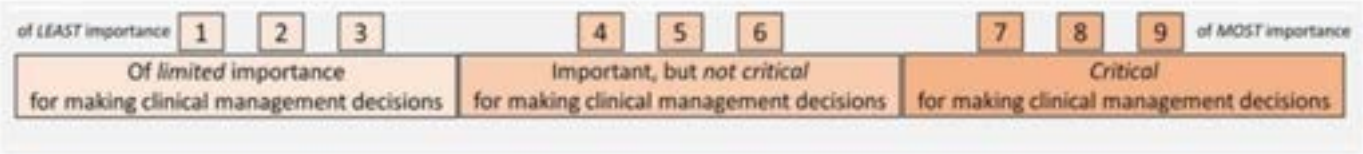
16

New Question

How important is your institution's comfort level in the use of neuromonitoring when determining the clinical utility of multimodality neuromonitoring for a patient?



1 2 3 4 5 6 7 8 9

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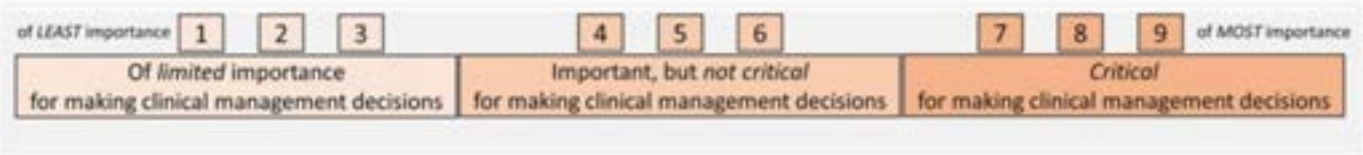
17

How important is the perception of the medical team that a certain prognosis is inevitable when determining the clinical utility of multimodality neuromonitoring for a patient?

Round 1: Median [IQR] 6 [5.25-7]

N.B. this question does not refer to limiting or withdrawing care, but rather the perception that neuromonitoring will make no impact on a perceived inevitable outcome



1 2 3 4 5 6 7 8 9

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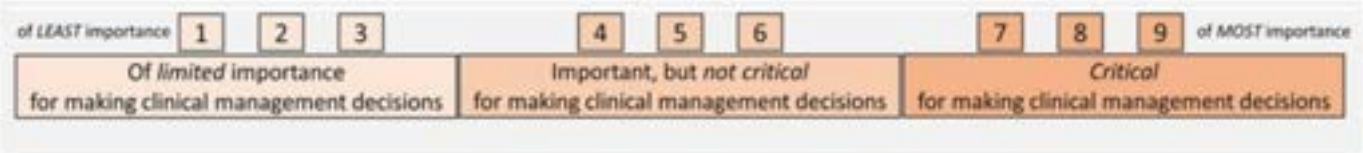
18

How important is age (either too young or too old) when determining the clinical utility of multimodality neuromonitoring for a patient?

Round 1: Median [IQR] 5 [3-6]

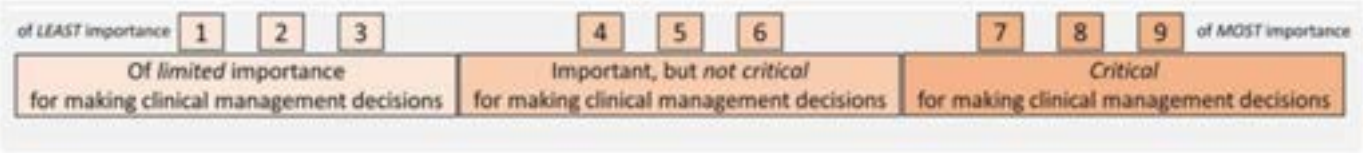


1 2 3 4 5 6 7 8 9

19

How important are structural imaging findings when determining the clinical utility of multimodality neuromonitoring for a patient?

Round 1: Median [IQR] 7 [6-7.75]

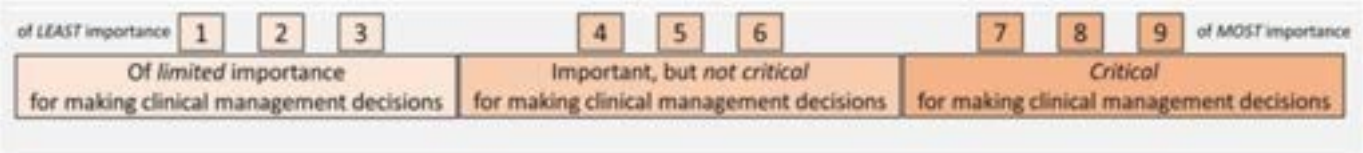


1 2 3 4 5 6 7 8 9

20

How important is multimodality neuromonitoring in guiding individualized management decisions for a patient?

Round 1: Median [IQR] 8 [7-8]

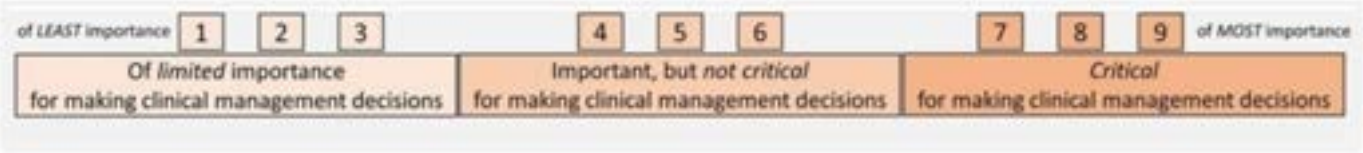


1 2 3 4 5 6 7 8 9

21

How important is multimodality neuromonitoring in informing goals or thresholds for targeted management in a patient?

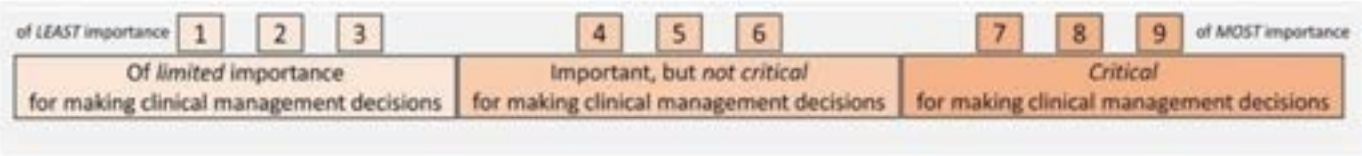
Round 1: Median [IQR] 8 [7-8]



1 2 3 4 5 6 7 8 9

New Question

How important is multimodality neuromonitoring in *abstaining from* or *de-escalating* a potential therapy or treatment that might cause harm?



1 2 3 4 5 6 7 8 9

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Contexts of Use: Case Presentations

For all questions, please do not consider cost, relative contraindications such as coagulopathy, or barriers to the placement of intracranial devices. If you would not be primarily caring for a patient as described by the questions below, answer to the best of your ability based on your experience.

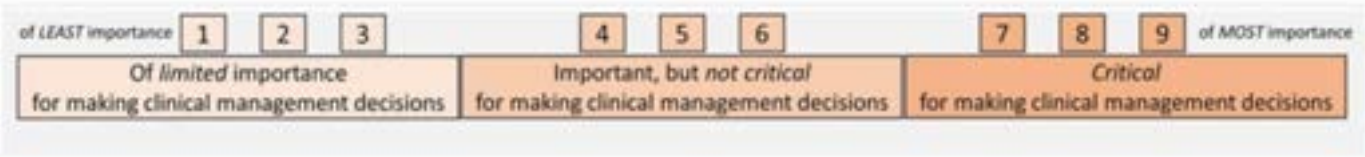
If your primary practice is PEDIATRIC, answer all questions below considering a child admitted to the Pediatric Intensive Care Unit for which there is a reasonable prognostic outlook and for whom all available brain monitoring would be used with a focus on invasive neuromonitoring devices or neuromonitoring devices with more than minimal risk.

If your primary practice involves ADULTS only, answer all questions below considering a middle-aged adult admitted to the Intensive Care Unit for which there is a reasonable prognostic outlook and for whom all available brain monitoring would be used with a focus on invasive neuromonitoring devices or neuromonitoring devices with more than minimal risk.

23

How important is multimodality neuromonitoring in a patient presenting with:
a.) non-surgical traumatic brain injury
b.) who remains comatose (GCS 8 or less) after initial resuscitation?

Round 1: Median [IQR] 9 [8-9]

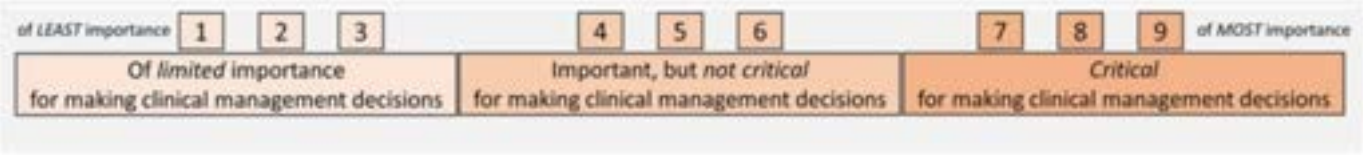


1 2 3 4 5 6 7 8 9

24

How important is multimodality neuromonitoring in a patient presenting with:
a.) non-surgical traumatic brain injury
b.) who has an abnormal neurological exam but is able to follow commands (GCS 9-12) after initial resuscitation?

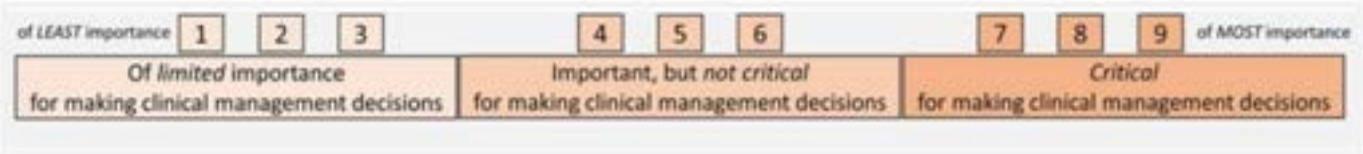
Round 1: Median [IQR] 6 [3.25-6]



1 2 3 4 5 6 7 8 9

25

New Question
How important is multimodality neuromonitoring in a patient presenting with:
a.) non-surgical traumatic brain injury
b.) who has an abnormal neurological exam but is able to follow commands (GCS 9-12) after initial resuscitation
c.) with spinal cord injury or significant long bone fractures that limit motor examination and require early or urgent major surgery?

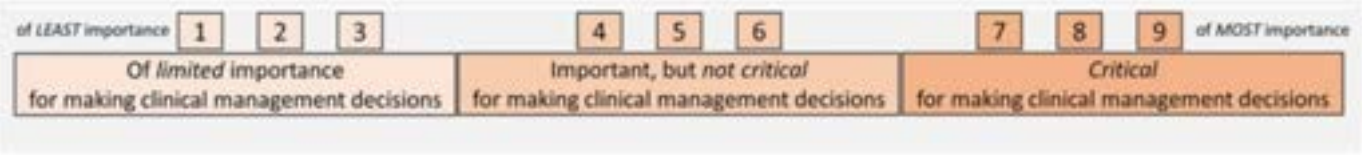


1 2 3 4 5 6 7 8 9

26

How important is multimodality neuromonitoring in a patient presenting with:
a.) surgical traumatic brain injury
b.) who remains comatose (GCS 8 or less) after appropriate evacuation and/or decompression?

Round 1: Median [IQR] 8 [7-9]

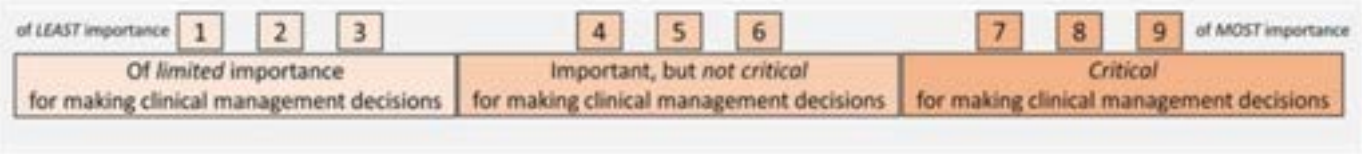


1 2 3 4 5 6 7 8 9

27

How important is multimodality neuromonitoring in a patient presenting with:
a.) surgical traumatic brain injury
b.) who has an abnormal neurological exam but is able to follow commands (GCS 9-12) after appropriate evacuation and/or decompression?

Round 1: Median [IQR] 5 [4-6]

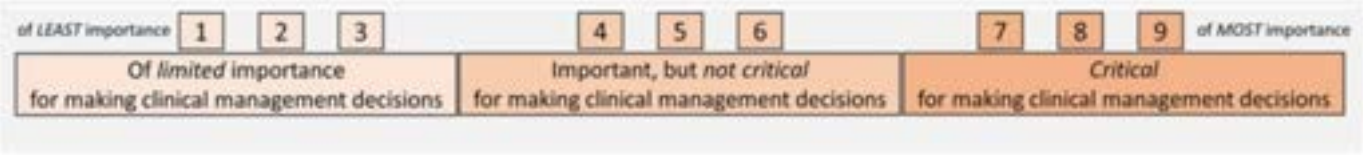


1 2 3 4 5 6 7 8 9

28

How important is multimodality neuromonitoring in a patient presenting with:
a.) aneurysmal subarachnoid hemorrhage
b.) who remains comatose (Hunt-Hess 4-5) after initial resuscitation and/or treatment of hydrocephalus?

Round 1: Median [IQR] 8.5 [7-9]

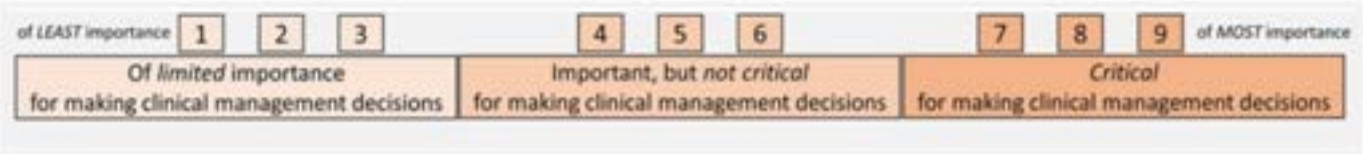


1 2 3 4 5 6 7 8 9

29

How important is multimodality neuromonitoring in a patient presenting with:
a.) aneurysmal subarachnoid hemorrhage
b.) who has an abnormal neurological exam but is able to follow commands (Hunt-Hess 3-4) after initial resuscitation and/or treatment of hydrocephalus?

Round 1: Median [IQR] 6 [5-7]

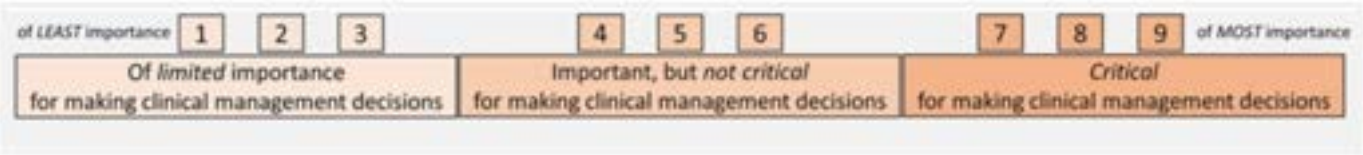


1 2 3 4 5 6 7 8 9

30

How important is multimodality neuromonitoring in a patient presenting with:
a.) aneurysmal subarachnoid hemorrhage
b.) who has developed vasospasm or vasospasm-associated delayed cerebral ischemia
c.) and who is comatose or ventilated on sedation?

Round 1: Median [IQR] 9 [8-9]

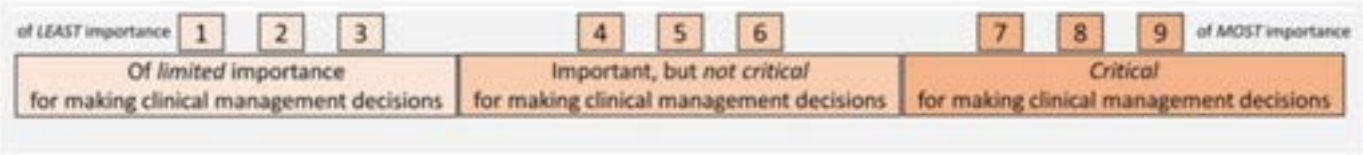


1 2 3 4 5 6 7 8 9

31

How important is multimodality neuromonitoring in a patient presenting with:
a.) supratentorial (lobar or basal ganglia) intracerebral hemorrhage without intraventricular hemorrhage
b.) who is comatose (GCS 8 or less)?

Round 1: Median [IQR] 7 [6-9]

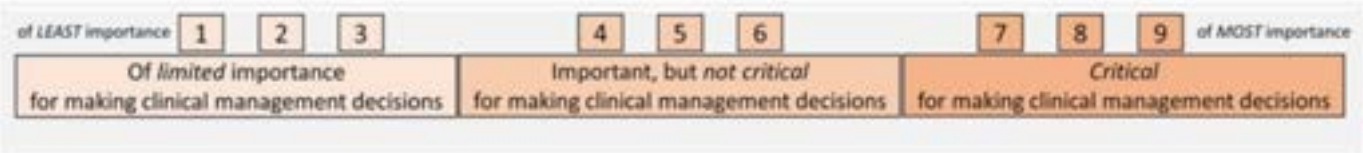


1 2 3 4 5 6 7 8 9

32

How important is multimodality neuromonitoring in a patient presenting with:
a.) supratentorial (lobar or basal ganglia) intracerebral hemorrhage with intraventricular extension
b.) who is comatose (GCS 8 or less) after treatment of hydrocephalus?

Round 1: Median [IQR] 7 [6-9]

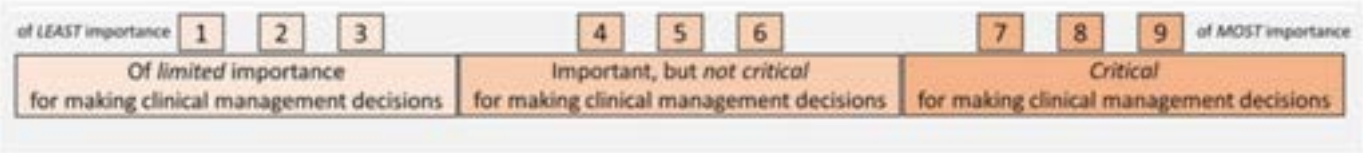


1 2 3 4 5 6 7 8 9

33

How important is multimodality neuromonitoring in a patient presenting with:
a.) supratentorial (lobar or basal ganglia) intracerebral hemorrhage +/- intraventricular extension
b.) who has an abnormal neurological exam but is able to follow commands (GCS 9-12)?

Round 1: Median [IQR] 5 [4-6]

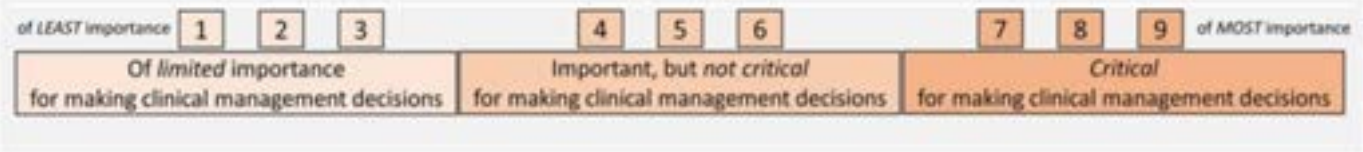


1 2 3 4 5 6 7 8 9

34

How important is multimodality neuromonitoring in a patient presenting with:
a.) hemispheric ischemic stroke at-risk for malignant edema not yet committed to surgical decompression?

Round 1: Median [IQR] 5 [3-7.75]

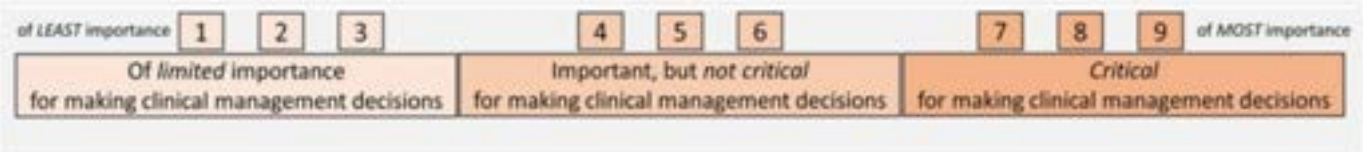


1 2 3 4 5 6 7 8 9

35

How important is multimodality neuromonitoring in a patient presenting with:
a.) hemispheric ischemic stroke with malignant edema following adequate surgical decompression?

Round 1: Median [IQR] 5 [3.25-7]

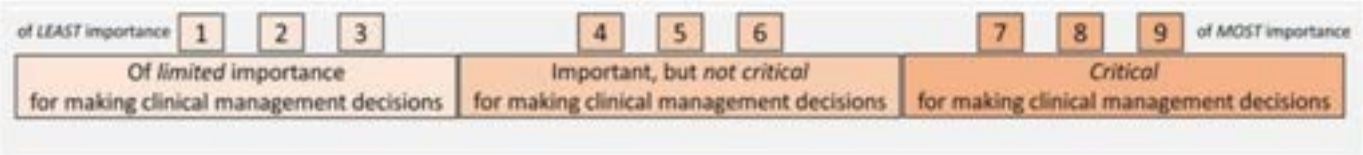


1 2 3 4 5 6 7 8 9

36

How important is multimodality neuromonitoring in a patient presenting with:
a.) super-refractory status epilepticus requiring multiple anesthetic medications?

Round 1: Median [IQR] 8 [5.25-9]

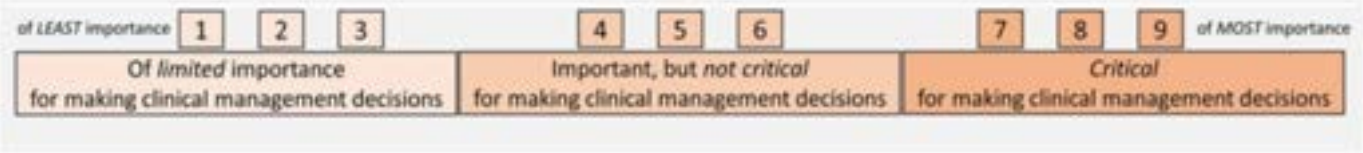


1 2 3 4 5 6 7 8 9

37

How important is multimodality neuromonitoring in a patient presenting with:
a.) infectious or presumed infectious encephalitis/meningitis
b.) who is comatose (GCS 8 or less) without evidence of seizures, hydrocephalus, or other causes of coma?

Round 1: Median [IQR] 6 [5-8]

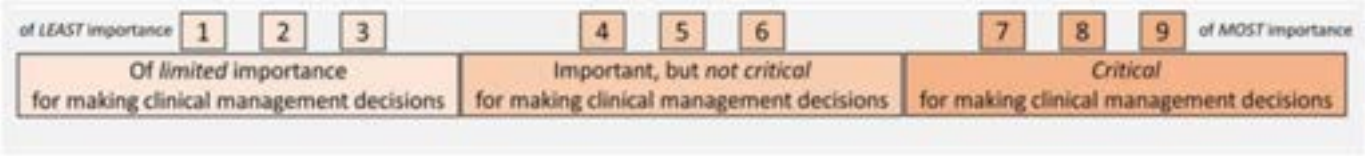


1 2 3 4 5 6 7 8 9

38

How important is multimodality neuromonitoring in a patient presenting with:
a.) sinus thrombosis or PRES with cerebral edema at risk for herniation
b.) who is comatose (GCS 8 or less)?

Round 1: Median [IQR] 7.5 [6-9]

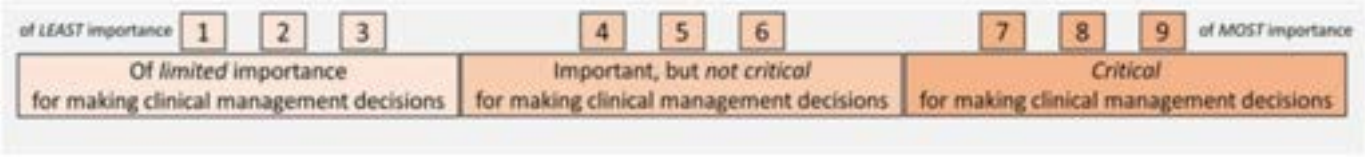


1 2 3 4 5 6 7 8 9

39

How important is multimodality neuromonitoring in a patient presenting with:
a.) RCVS or other vasculopathy at risk for evolving ischemia
b.) who is comatose (GCS 8 or less)?

Round 1: Median [IQR] 6 [5.25-8.75]



1 2 3 4 5 6 7 8 9

40

How important is multimodality neuromonitoring in a patient presenting with:
a.) following cardiac arrest
b.) with short downtime, no past medical history, and normal CT
c.) who is comatose during TTM (i.e. within 24 hours of arrest)?

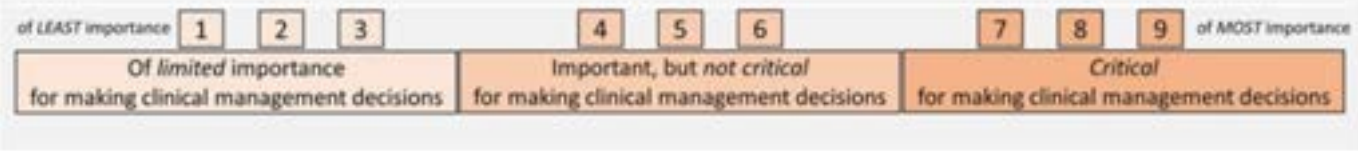
Round 1: Median [IQR] 6 [5-8]

1 2 3 4 5 6 7 8 9

41

How important is multimodality neuromonitoring in a patient presenting with:
a.) following cardiac arrest
b.) with short downtime, no past medical history, and normal CT
c.) who is comatose after rewarming (i.e. > 24 hours after arrest)?

Round 1: Median [IQR] 7 [5.25-8.75]

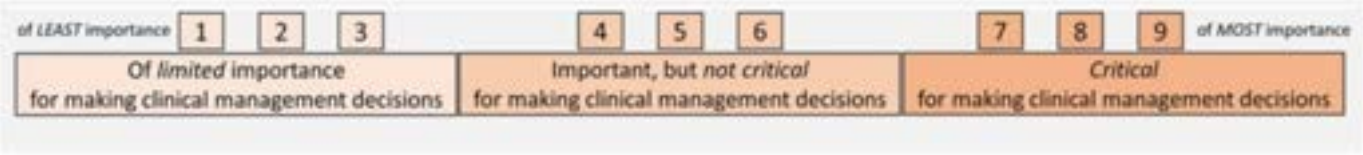


1 2 3 4 5 6 7 8 9

42

How important is multimodality neuromonitoring in a patient presenting with:
a.) following cardiac arrest
b.) with no past medical history and normal CT
c.) who is comatose and develops clinical post-anoxic myoclonus early after injury?

Round 1: Median [IQR] 7 [6-8]

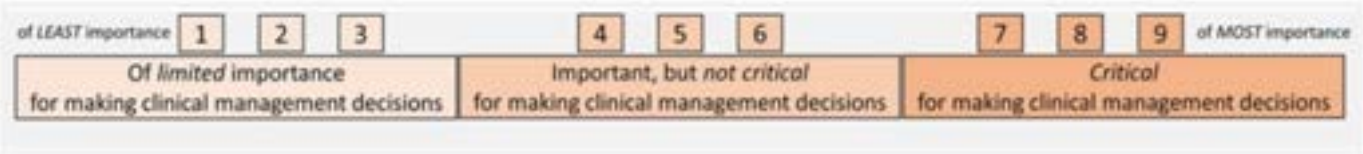


1 2 3 4 5 6 7 8 9

43

How important is multimodality neuromonitoring in a patient presenting with:
a.) following cardiac arrest
b.) with short downtime, no past medical history
c.) and clinical or radiographic concern for cerebral edema?

Round 1: Median [IQR] 6 [5-8]

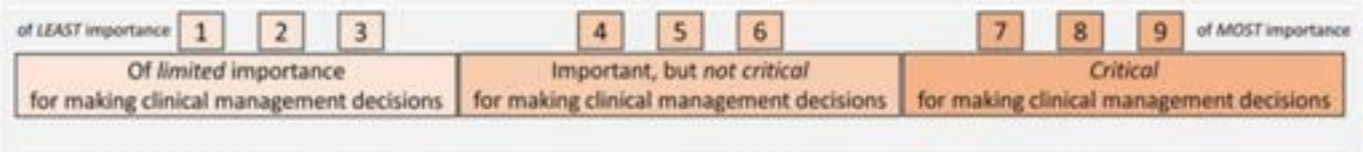


1 2 3 4 5 6 7 8 9

44

New Question

How important is multimodality neuromonitoring in a patient presenting with:
a.) no structural injury on imaging
b.) and who requires deep sedation, anesthesia, or paralytics for non-neurological reasons (e.g. ventilatory support)
c.) and is at-risk for unstable hemodynamics?

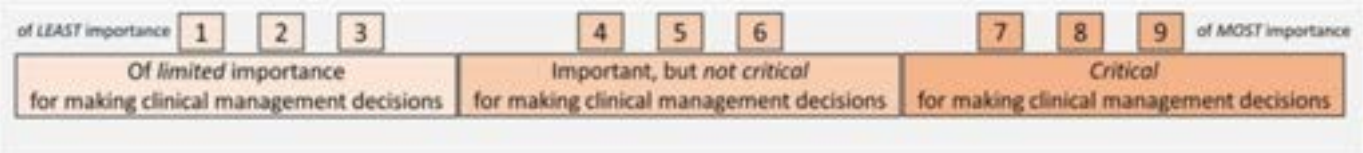


1 2 3 4 5 6 7 8 9

45

How important is multimodality neuromonitoring in a patient presenting with:
a.) toxic-metabolic encephalopathy (e.g. severe hyperglycemia or hyponatremia)
b.) clinical or radiographic concern for cerebral edema
c.) who is comatose (GCS 8 or less)?

Round 1: Median [IQR] 6 [5-8]

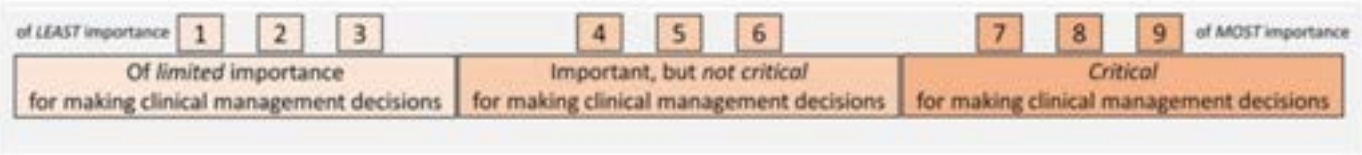


1 2 3 4 5 6 7 8 9

46

How important is multimodality neuromonitoring in a patient presenting with:
a.) toxic-metabolic encephalopathy (e.g. severe hyperglycemia or hyponatremia)
b.) clinical or radiographic concern for cerebral edema
c.) who has an abnormal neurological exam but is able to follow commands (GCS 9-12)?

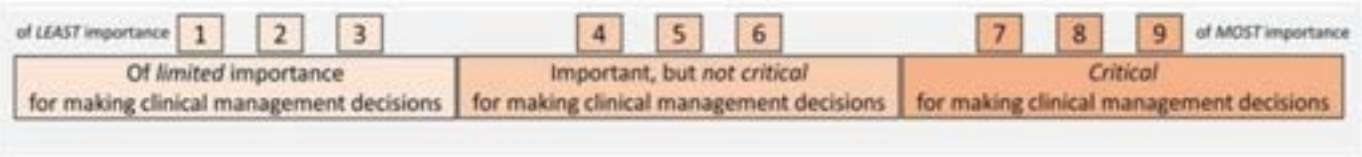
Round 1: Median [IQR] 5 [3-6]



1 2 3 4 5 6 7 8 9

47

New Question
How important is multimodality neuromonitoring in a patient presenting with:
a.) genetic metabolic disorder with or without seizures
b.) at-risk for metabolic decompensation and global cerebral edema
c.) who is comatose (GCS 8 or less)?

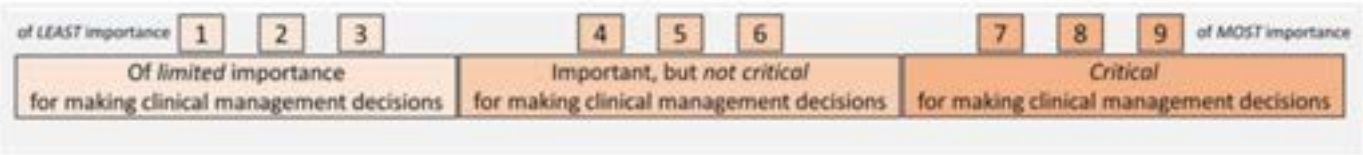


1 2 3 4 5 6 7 8 9

48

How important is multimodality neuromonitoring in a patient presenting with:
a.) cytokine release syndrome-related encephalopathy (e.g. COVID-related, CAR T-cell neurotoxicity syndrome) or other inflammatory condition
b.) clinical or radiographic concern for cerebral edema
c.) who is comatose (GCS 8 or less)

Round 1: Median [IQR] 7 [5-8]



1 2 3 4 5 6 7 8 9

49

How important is multimodality neuromonitoring in a patient presenting with:
a.) fulminant hepatic failure
b.) clinical or radiographic concern for cerebral edema
c.) who is comatose (West Haven Stage 4)

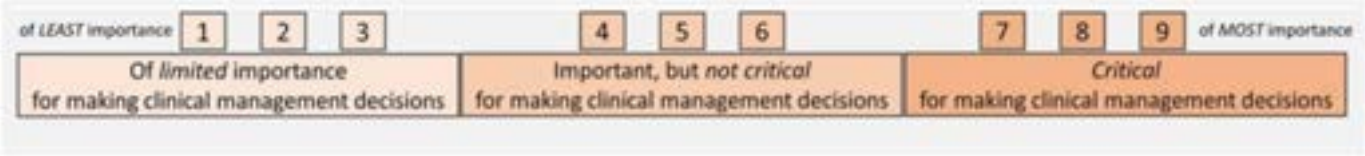
Round 1: Median [IQR] 7 [5.25-8.75]

1 2 3 4 5 6 7 8 9

50

How important is multimodality neuromonitoring in a patient presenting with:
a.) cardiopulmonary failure
b.) requiring veno-arterial extracorporeal membrane oxygenation (VA-ECMO)

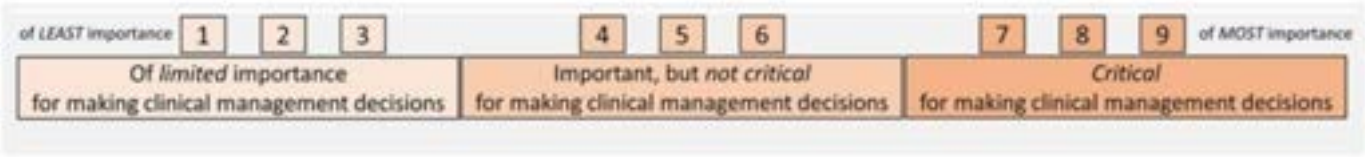
Round 1: Median [IQR] 6 [3-7]



1 2 3 4 5 6 7 8 9

51

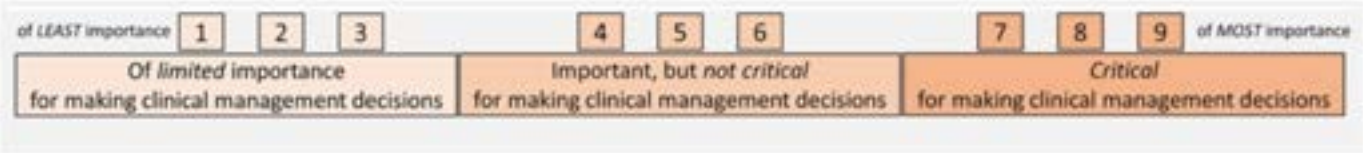
New Question
How important is multimodality neuromonitoring in a patient presenting with:
a.) severe acute respiratory failure (e.g. acute respiratory distress syndrome [ARDS])
b.) requiring venovenous extracorporeal membrane oxygenation (VV-ECMO)



1 2 3 4 5 6 7 8 9

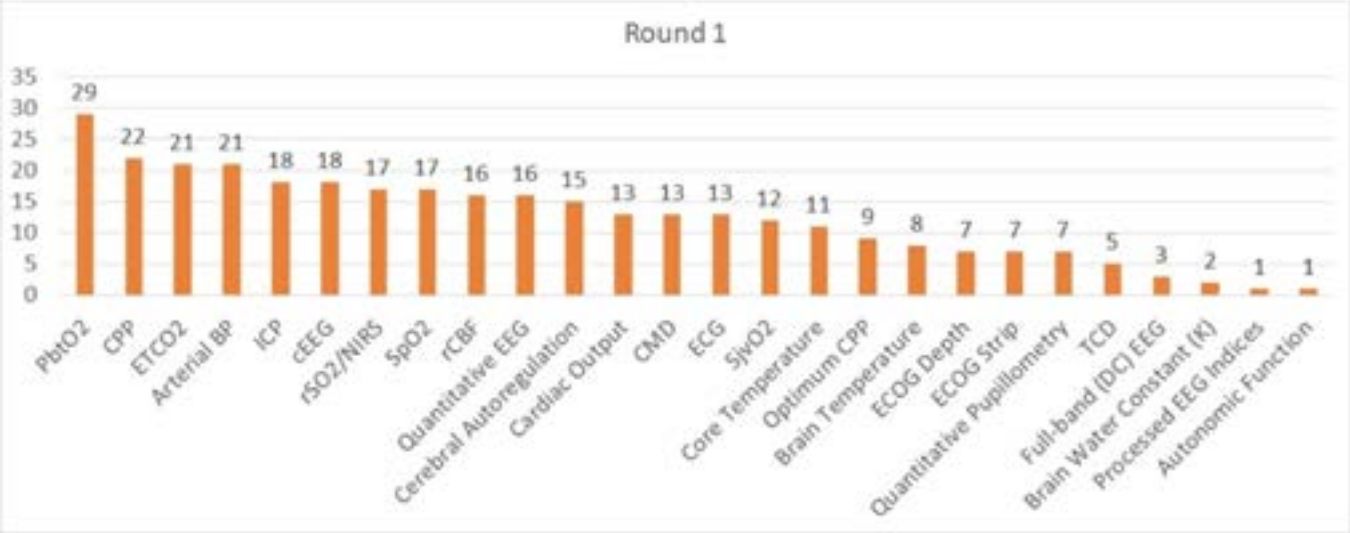
How important is multimodality neuromonitoring in a patient presenting with:
a.) sepsis
b.) who is comatose (GCS 8 or less) due to underlying septic encephalopathy or shock

Round 1: Median [IQR] 5.5 [3-7]



1 2 3 4 5 6 7 8 9

Contexts of Use: BRAIN TISSUE HYPOXIA

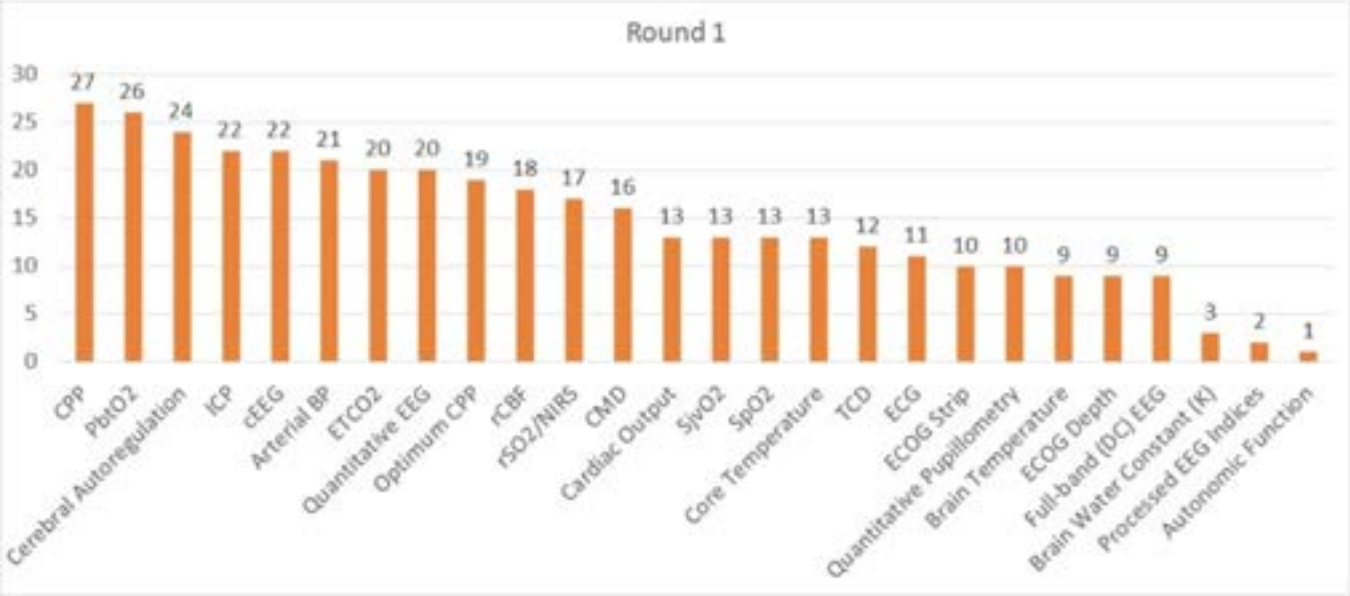


Select EACH of the physiologic measurements that you feel are useful to detect and optimally manage BRAIN TISSUE HYPOXIA of any cause:

- [ ] Intracranial Pressure (ICP)
- [ ] Cardiac Output (including associated measures of intravascular volume)
- [ ] Cerebral Perfusion Pressure (CPP)
- [ ] Optimal Cerebral Perfusion Pressure (CPPopt)
- [ ] Cerebral Autoregulation (e.g. PRx, Mx, ORx)
- [ ] End-Tidal Capnography (ETCO2)
- [ ] Brain Tissue Oxygen (PbtO2 or PtiO2)
- [ ] Jugular Venous Oxygen (SjvO2)
- [ ] Regional Oxygen Saturation (rSO2) using Near-Infrared Spectroscopy (NIRS) or other optical imaging technology
- [ ] Regional Cerebral Blood Flow (rCBF)
- [ ] Brain Temperature
- [ ] Brain Water Constant (K)
- [ ] Cerebral Microdialysis
- [ ] Continuous Scalp EEG
- [ ] Electrocorticography: Single-wire or Depth Electrode
- [ ] Electrocorticography: Strip Electrode
- [ ] Full-band (DC or near-DC) EEG Recordings
- [ ] Quantitative EEG
- [ ] Processed EEG Indices of Anesthesia/Sedation Depth
- [ ] Quantitative Pupillometry
- [ ] Extended-Duration (> 30 min) or Frequent (> 1 daily) Transcranial Doppler Ultrasonography (TCD)

- [ ] Autonomic Function (e.g. heart rate variability)
- [ ] Arterial Blood Pressure (ABP)
- [ ] Cardiac Telemetry (ECG)
- [ ] Plethysmography (SpO2)
- [ ] Continuous Core Body Temperature or Continuous Water Temperature (in patients undergoing targeted temperature management)

Contexts of Use: CEREBRAL ISCHEMIA

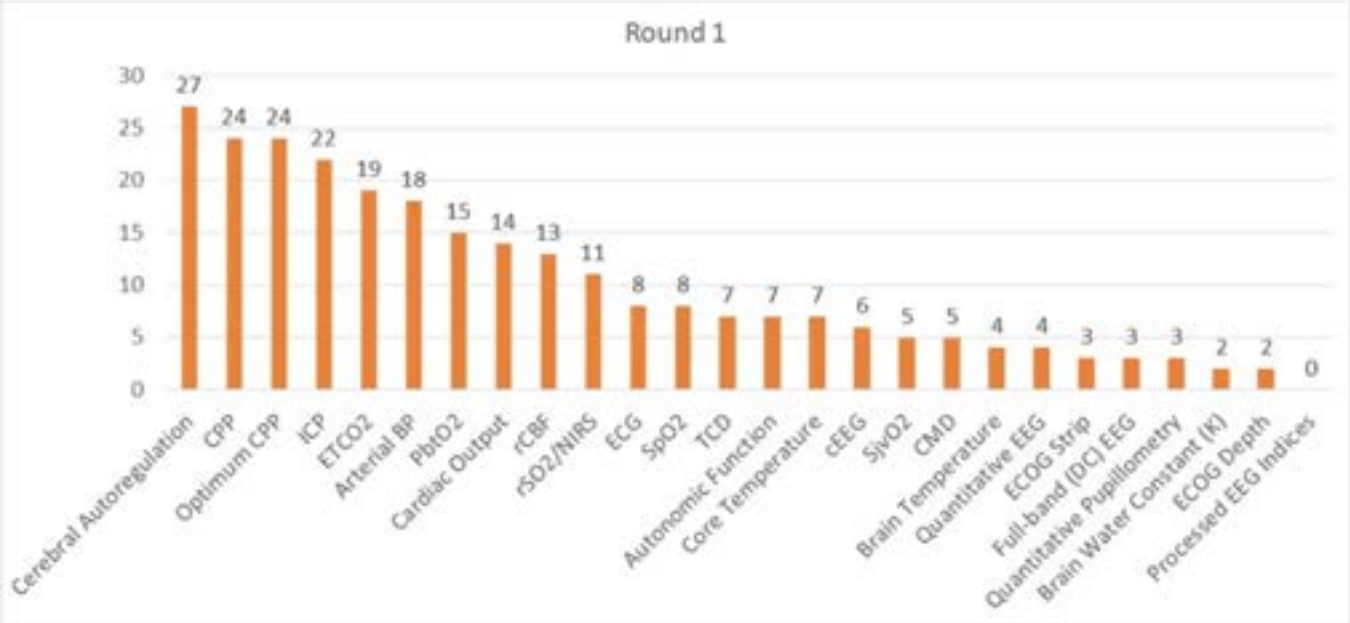


Select EACH of the physiologic measurements that you feel are useful to detect and optimally manage CEREBRAL ISCHEMIA of any cause (including subarachnoid hemorrhage-related delayed cerebral ischemia):

- [ ] Intracranial Pressure (ICP)
- [ ] Cardiac Output (including associated measures of intravascular volume)
- [ ] Cerebral Perfusion Pressure (CPP)
- [ ] Optimal Cerebral Perfusion Pressure (CPPopt)
- [ ] Cerebral Autoregulation (e.g. PRx, Mx, ORx)
- [ ] End-Tidal Capnography ($ETCO_2$)
- [ ] Brain Tissue Oxygen ($PbtO_2$ or $PtiO_2$)
- [ ] Jugular Venous Oxygen ($SjvO_2$)
- [ ] Regional Oxygen Saturation (rSO_2) using Near-Infrared Spectroscopy (NIRS) or other optical imaging technology
- [ ] Regional Cerebral Blood Flow (rCBF)
- [ ] Brain Temperature
- [ ] Brain Water Constant (K)
- [ ] Cerebral Microdialysis
- [ ] Continuous Scalp EEG
- [ ] Electrocorticography: Single-wire or Depth Electrode
- [ ] Electrocorticography: Strip Electrode
- [ ] Full-band (DC or near-DC) EEG Recordings
- [ ] Quantitative EEG
- [ ] Processed EEG Indices of Anesthesia/Sedation Depth
- [ ] Quantitative Pupillometry
- [ ] Extended-Duration (> 30 min) or Frequent (> 1 daily) Transcranial Doppler Ultrasonography (TCD)

- [ ] Autonomic Function (e.g. heart rate variability)
- [ ] Arterial Blood Pressure (ABP)
- [ ] Cardiac Telemetry (ECG)
- [ ] Plethysmography (SpO2)
- [ ] Continuous Core Body Temperature or Continuous Water Temperature (in patients undergoing targeted temperature management)

Contexts of Use: AUTOREGULATORY DYSFUNCTION



Select EACH of the physiologic measurements that you feel are useful to detect and optimally manage AUTOREGULATORY DYSFUNCTION:

- [ ] Intracranial Pressure (ICP)
- [ ] Cardiac Output (including associated measures of intravascular volume)
- [ ] Cerebral Perfusion Pressure (CPP)
- [ ] Optimal Cerebral Perfusion Pressure (CPPopt)
- [ ] Cerebral Autoregulation (e.g. PRx, Mx, ORx)
- [ ] End-Tidal Capnography (ETCO2)
- [ ] Brain Tissue Oxygen (PbtO2 or PtiO2)
- [ ] Jugular Venous Oxygen (SjvO2)
- [ ] Regional Oxygen Saturation (rSO2) using Near-Infrared Spectroscopy (NIRS) or other optical imaging technology
- [ ] Regional Cerebral Blood Flow (rCBF)
- [ ] Brain Temperature
- [ ] Brain Water Constant (K)
- [ ] Cerebral Microdialysis
- [ ] Continuous Scalp EEG
- [ ] Electrocorticography: Single-wire or Depth Electrode
- [ ] Electrocorticography: Strip Electrode
- [ ] Full-band (DC or near-DC) EEG Recordings
- [ ] Quantitative EEG
- [ ] Processed EEG Indices of Anesthesia/Sedation Depth
- [ ] Quantitative Pupillometry
- [ ] Extended-Duration (> 30 min) or Frequent (> 1 daily) Transcranial Doppler Ultrasonography (TCD)

- [ ] Autonomic Function (e.g. heart rate variability)
- [ ] Arterial Blood Pressure (ABP)
- [ ] Cardiac Telemetry (ECG)
- [ ] Plethysmography (SpO2)
- [ ] Continuous Core Body Temperature or Continuous Water Temperature (in patients undergoing targeted temperature management)

Contexts of Use: ACUTE COMA OR DISORDERS OF CONSCIOUSNESS

New Question

Select EACH of the physiologic measurements that you feel are useful to detect and optimally manage ACUTE COMA OR DISORDERS OF CONSCIOUSNESS:

- [ ] Intracranial Pressure (ICP)
- [ ] Cardiac Output (including associated measures of intravascular volume)
- [ ] Cerebral Perfusion Pressure (CPP)
- [ ] Optimal Cerebral Perfusion Pressure (CPPopt)
- [ ] Cerebral Autoregulation (e.g. PRx, Mx, ORx)
- [ ] End-Tidal Capnography (ETCO2)
- [ ] Brain Tissue Oxygen (PbtO2 or PtiO2)
- [ ] Jugular Venous Oxygen (SjvO2)
- [ ] Regional Oxygen Saturation (rSO2) using Near-Infrared Spectroscopy (NIRS) or other optical imaging technology
- [ ] Regional Cerebral Blood Flow (rCBF)
- [ ] Brain Temperature
- [ ] Brain Water Constant (K)
- [ ] Cerebral Microdialysis
- [ ] Continuous Scalp EEG
- [ ] Electrocorticography: Single-wire or Depth Electrode
- [ ] Electrocorticography: Strip Electrode
- [ ] Full-band (DC or near-DC) EEG Recordings
- [ ] Quantitative EEG
- [ ] Processed EEG Indices of Anesthesia/Sedation Depth
- [ ] Quantitative Pupillometry
- [ ] Extended-Duration (> 30 min) or Frequent (> 1 daily) Transcranial Doppler Ultrasonography (TCD)

- [ ] Autonomic Function (e.g. heart rate variability)
- [ ] Arterial Blood Pressure (ABP)
- [ ] Cardiac Telemetry (ECG)
- [ ] Plethysmography (SpO2)
- [ ] Continuous Core Body Temperature or Continuous Water Temperature (in patients undergoing targeted temperature management)

Contexts of Use: POST-CARDIAC ARREST ANOXIC BRAIN INJURY

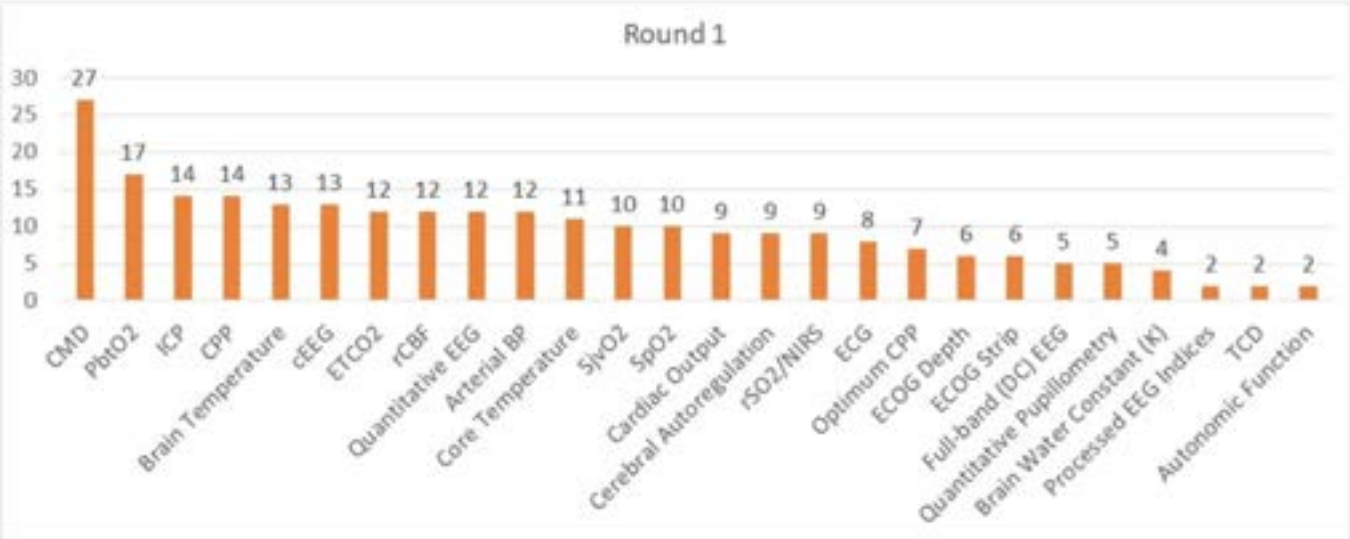
New Question

Select EACH of the physiologic measurements that you feel are useful to detect and optimally manage POST-CARDIAC ARREST ANOXIC BRAIN INJURY:

- [ ] Intracranial Pressure (ICP)
- [ ] Cardiac Output (including associated measures of intravascular volume)
- [ ] Cerebral Perfusion Pressure (CPP)
- [ ] Optimal Cerebral Perfusion Pressure (CPPopt)
- [ ] Cerebral Autoregulation (e.g. PRx, Mx, ORx)
- [ ] End-Tidal Capnography (ETCO2)
- [ ] Brain Tissue Oxygen (PbtO2 or PtiO2)
- [ ] Jugular Venous Oxygen (SjvO2)
- [ ] Regional Oxygen Saturation (rSO2) using Near-Infrared Spectroscopy (NIRS) or other optical imaging technology
- [ ] Regional Cerebral Blood Flow (rCBF)
- [ ] Brain Temperature
- [ ] Brain Water Constant (K)
- [ ] Cerebral Microdialysis
- [ ] Continuous Scalp EEG
- [ ] Electrocorticography: Single-wire or Depth Electrode
- [ ] Electrocorticography: Strip Electrode
- [ ] Full-band (DC or near-DC) EEG Recordings
- [ ] Quantitative EEG
- [ ] Processed EEG Indices of Anesthesia/Sedation Depth
- [ ] Quantitative Pupillometry
- [ ] Extended-Duration (> 30 min) or Frequent (> 1 daily) Transcranial Doppler Ultrasonography (TCD)

- [ ] Autonomic Function (e.g. heart rate variability)
- [ ] Arterial Blood Pressure (ABP)
- [ ] Cardiac Telemetry (ECG)
- [ ] Plethysmography (SpO2)
- [ ] Continuous Core Body Temperature or Continuous Water Temperature (in patients undergoing targeted temperature management)

Contexts of Use: METABOLIC CRISIS OR MITOCHONDRIAL DYSFUNCTION

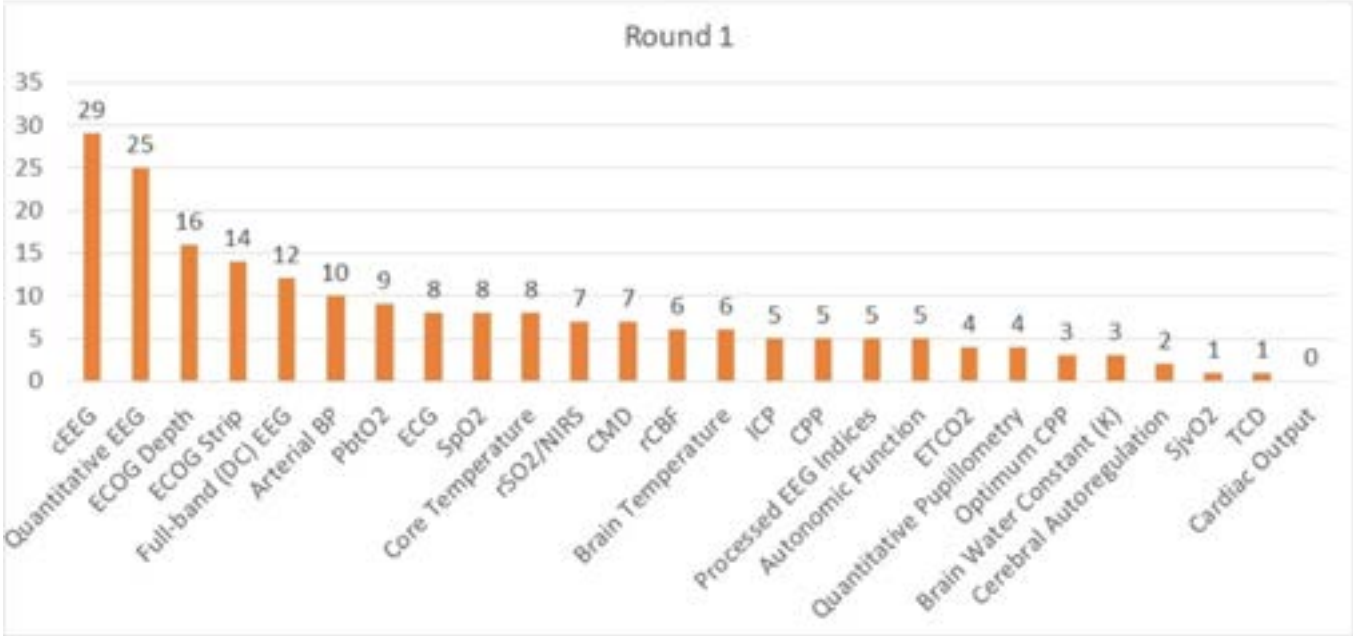


Select EACH of the physiologic measurements that you feel are useful to detect and optimally manage METABOLIC CRISIS OR MITOCHONDRIAL DYSFUNCTION:

- [ ] Intracranial Pressure (ICP)
- [ ] Cardiac Output (including associated measures of intravascular volume)
- [ ] Cerebral Perfusion Pressure (CPP)
- [ ] Optimal Cerebral Perfusion Pressure (CPPopt)
- [ ] Cerebral Autoregulation (e.g. PRx, Mx, ORx)
- [ ] End-Tidal Capnography (ETCO2)
- [ ] Brain Tissue Oxygen (PbtO2 or PtiO2)
- [ ] Jugular Venous Oxygen (SjvO2)
- [ ] Regional Oxygen Saturation (rSO2) using Near-Infrared Spectroscopy (NIRS) or other optical imaging technology
- [ ] Regional Cerebral Blood Flow (rCBF)
- [ ] Brain Temperature
- [ ] Brain Water Constant (K)
- [ ] Cerebral Microdialysis
- [ ] Continuous Scalp EEG
- [ ] Electrocorticography: Single-wire or Depth Electrode
- [ ] Electrocorticography: Strip Electrode
- [ ] Full-band (DC or near-DC) EEG Recordings
- [ ] Quantitative EEG
- [ ] Processed EEG Indices of Anesthesia/Sedation Depth
- [ ] Quantitative Pupillometry
- [ ] Extended-Duration (> 30 min) or Frequent (> 1 daily) Transcranial Doppler Ultrasonography (TCD)

- [ ] Autonomic Function (e.g. heart rate variability)
- [ ] Arterial Blood Pressure (ABP)
- [ ] Cardiac Telemetry (ECG)
- [ ] Plethysmography (SpO2)
- [ ] Continuous Core Body Temperature or Continuous Water Temperature (in patients undergoing targeted temperature management)

Contexts of Use: SEIZURES OR ICTAL-INTERICTAL CONTINUUM PATTERNS

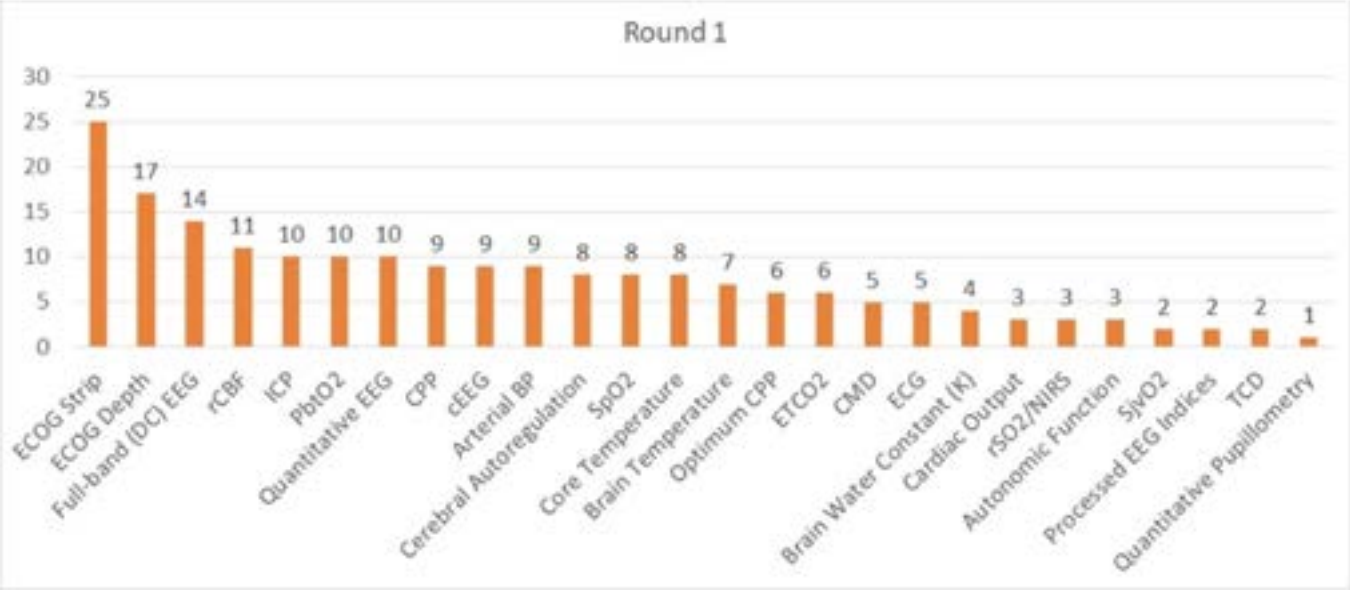


Select EACH of the physiologic measurements that you feel are useful to detect and optimally manage SEIZURES OR ICTAL-INTERICTAL CONTINUUM PATTERNS:

- [ ] Intracranial Pressure (ICP)
- [ ] Cardiac Output (including associated measures of intravascular volume)
- [ ] Cerebral Perfusion Pressure (CPP)
- [ ] Optimal Cerebral Perfusion Pressure (CPPopt)
- [ ] Cerebral Autoregulation (e.g. PRx, Mx, ORx)
- [ ] End-Tidal Capnography (ETCO2)
- [ ] Brain Tissue Oxygen (PbtO2 or PtiO2)
- [ ] Jugular Venous Oxygen (SjvO2)
- [ ] Regional Oxygen Saturation (rSO2) using Near-Infrared Spectroscopy (NIRS) or other optical imaging technology
- [ ] Regional Cerebral Blood Flow (rCBF)
- [ ] Brain Temperature
- [ ] Brain Water Constant (K)
- [ ] Cerebral Microdialysis
- [ ] Continuous Scalp EEG
- [ ] Electrocorticography: Single-wire or Depth Electrode
- [ ] Electrocorticography: Strip Electrode
- [ ] Full-band (DC or near-DC) EEG Recordings
- [ ] Quantitative EEG
- [ ] Processed EEG Indices of Anesthesia/Sedation Depth
- [ ] Quantitative Pupillometry
- [ ] Extended-Duration (> 30 min) or Frequent (> 1 daily) Transcranial Doppler Ultrasonography (TCD)

- [ ] Autonomic Function (e.g. heart rate variability)
- [ ] Arterial Blood Pressure (ABP)
- [ ] Cardiac Telemetry (ECG)
- [ ] Plethysmography (SpO2)
- [ ] Continuous Core Body Temperature or Continuous Water Temperature (in patients undergoing targeted temperature management)

Contexts of Use: SPREADING DEPOLARIZATIONS

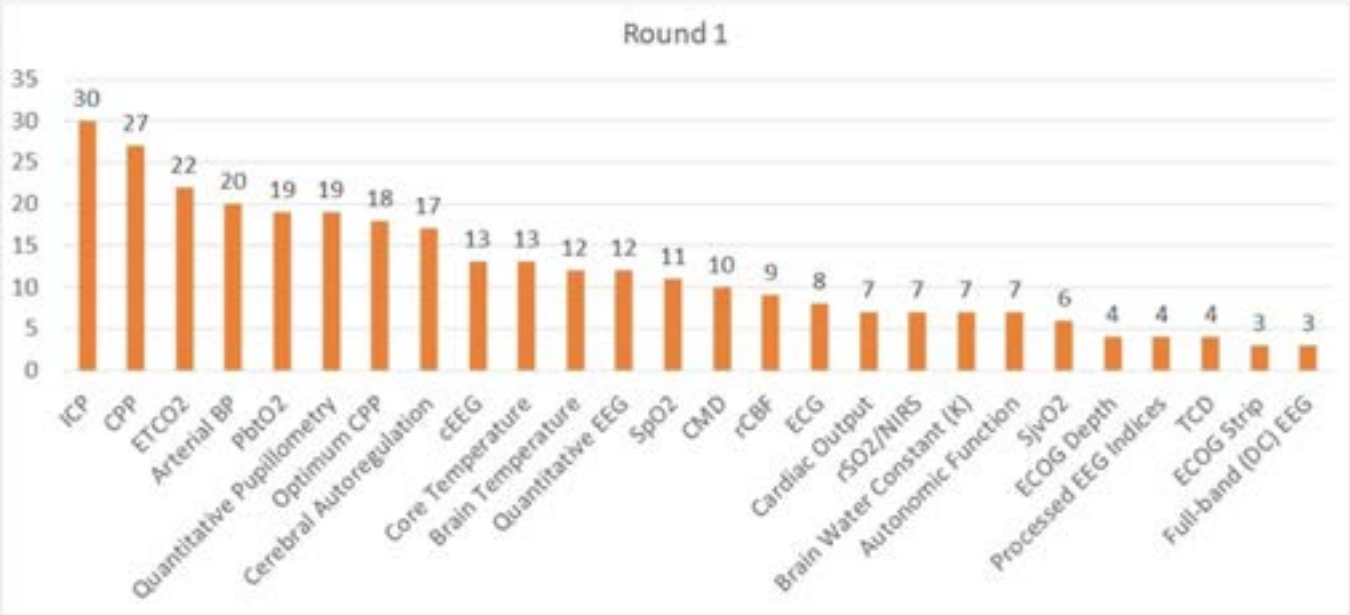


Select EACH of the physiologic measurements that you feel are useful to detect and optimally manage SPREADING DEPOLARIZATIONS:

- [ ] Intracranial Pressure (ICP)
- [ ] Cardiac Output (including associated measures of intravascular volume)
- [ ] Cerebral Perfusion Pressure (CPP)
- [ ] Optimal Cerebral Perfusion Pressure (CPPopt)
- [ ] Cerebral Autoregulation (e.g. PRx, Mx, ORx)
- [ ] End-Tidal Capnography (ETCO2)
- [ ] Brain Tissue Oxygen (PbtO2 or PtiO2)
- [ ] Jugular Venous Oxygen (SjvO2)
- [ ] Regional Oxygen Saturation (rSO2) using Near-Infrared Spectroscopy (NIRS) or other optical imaging technology
- [ ] Regional Cerebral Blood Flow (rCBF)
- [ ] Brain Temperature
- [ ] Brain Water Constant (K)
- [ ] Cerebral Microdialysis
- [ ] Continuous Scalp EEG
- [ ] Electrocorticography: Single-wire or Depth Electrode
- [ ] Electrocorticography: Strip Electrode
- [ ] Full-band (DC or near-DC) EEG Recordings
- [ ] Quantitative EEG
- [ ] Processed EEG Indices of Anesthesia/Sedation Depth
- [ ] Quantitative Pupillometry
- [ ] Extended-Duration (> 30 min) or Frequent (> 1 daily) Transcranial Doppler Ultrasonography (TCD)

- [ ] Autonomic Function (e.g. heart rate variability)
- [ ] Arterial Blood Pressure (ABP)
- [ ] Cardiac Telemetry (ECG)
- [ ] Plethysmography (SpO2)
- [ ] Continuous Core Body Temperature or Continuous Water Temperature (in patients undergoing targeted temperature management)

Contexts of Use: INTRACRANIAL HYPERTENSION OR HERNIATION



Select EACH of the physiologic measurements that you feel are useful to detect and optimally manage INTRACRANIAL HYPERTENSION OR HERNIATION:

- [ ] Intracranial Pressure (ICP)
- [ ] Cardiac Output (including associated measures of intravascular volume)
- [ ] Cerebral Perfusion Pressure (CPP)
- [ ] Optimal Cerebral Perfusion Pressure (CPPopt)
- [ ] Cerebral Autoregulation (e.g. PRx, Mx, ORx)
- [ ] End-Tidal Capnography (ETCO2)
- [ ] Brain Tissue Oxygen (PbtO2 or PtiO2)
- [ ] Jugular Venous Oxygen (SjvO2)
- [ ] Regional Oxygen Saturation (rSO2) using Near-Infrared Spectroscopy (NIRS) or other optical imaging technology
- [ ] Regional Cerebral Blood Flow (rCBF)
- [ ] Brain Temperature
- [ ] Brain Water Constant (K)
- [ ] Cerebral Microdialysis
- [ ] Continuous Scalp EEG
- [ ] Electrocorticography: Single-wire or Depth Electrode
- [ ] Electrocorticography: Strip Electrode
- [ ] Full-band (DC or near-DC) EEG Recordings
- [ ] Quantitative EEG
- [ ] Processed EEG Indices of Anesthesia/Sedation Depth
- [ ] Quantitative Pupillometry
- [ ] Extended-Duration (> 30 min) or Frequent (> 1 daily) Transcranial Doppler Ultrasonography (TCD)

- [ ] Autonomic Function (e.g. heart rate variability)
- [ ] Arterial Blood Pressure (ABP)
- [ ] Cardiac Telemetry (ECG)
- [ ] Plethysmography (SpO2)
- [ ] Continuous Core Body Temperature or Continuous Water Temperature (in patients undergoing targeted temperature management)

Minimum Necessary Technology: Devices & Measurements

How important are each of the following physiologic measurements and devices to your clinical decision-making?

For each question, consider a hypothetical patient who requires the MOST comprehensive multimodality neuromonitoring. Assume that you have access to any and all modalities listed below.

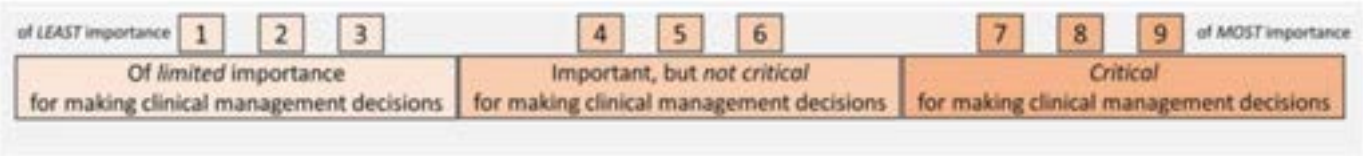
Your experience with specific devices/modalities may inform your decision. If you have *not* had access to a device in your practice but feel it might be useful, please rate as such based on your existing expertise. Please do not consider specific brands or types of devices, rather focus on the measurement parameter itself.

If a measurement modality is important only in conjunction with another measurement, BOTH should be rated as important. For example, if you feel cerebral autoregulation is extremely important and you measure it using rSO2, then rate both as extremely important even if you do not use rSO2 for anything else.

62

Intracranial Pressure (ICP)

Round 1: Median [IQR] 9 [8.25-9]

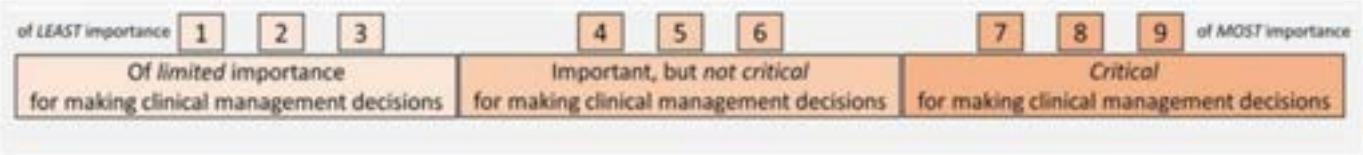


1 2 3 4 5 6 7 8 9

63

Cardiac Output (including associated measures of intravascular volume)

Round 1: Median [IQR] 6.5 [5.25-7]

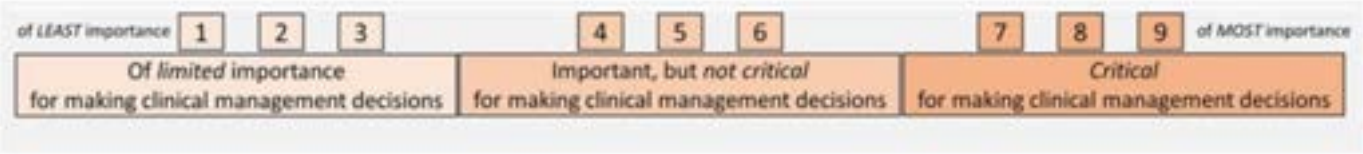


1 2 3 4 5 6 7 8 9

64

Cerebral Perfusion Pressure (CPP)

Round 1: Median [IQR] 8 [8-9]

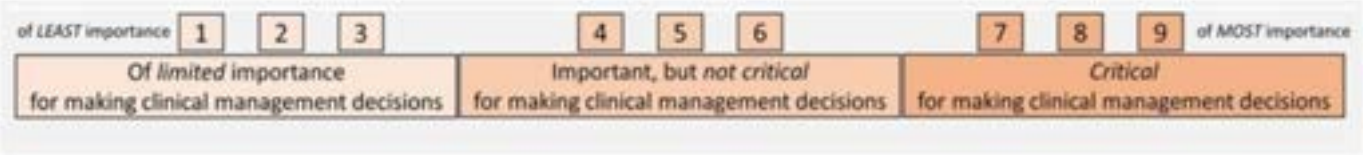


1 2 3 4 5 6 7 8 9

65

Optimal Cerebral Perfusion Pressure (CPPopt)

Round 1: Median [IQR] 6 [5-7]

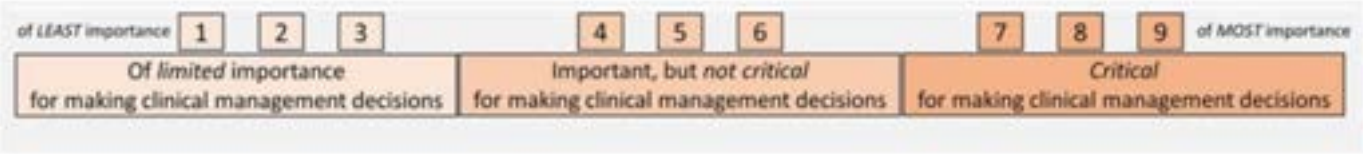


1 2 3 4 5 6 7 8 9

66

Cerebrovascular Autoregulation (e.g. PRx, Mx, ORx)

Round 1: Median [IQR] 7 [5.25-7.75]

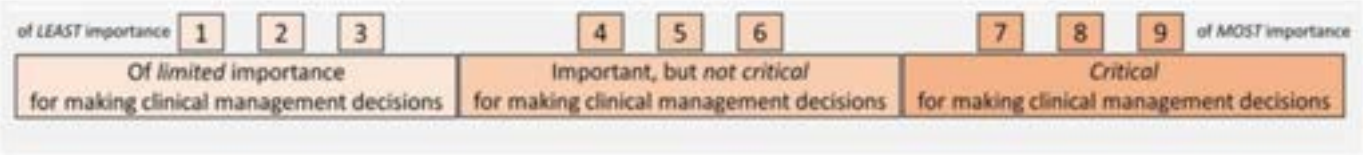


1 2 3 4 5 6 7 8 9

67

End-Tidal Capnography (ETCO2)

Round 1: Median [IQR] 8 [7-9]

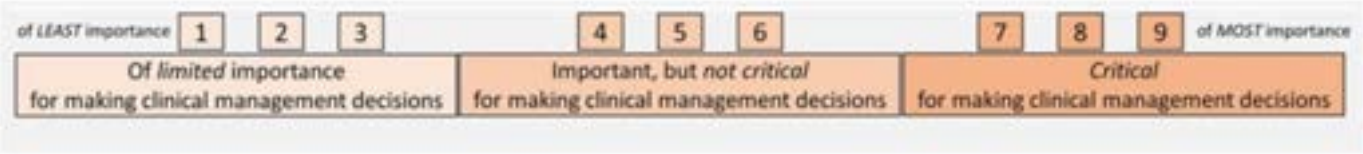


1 2 3 4 5 6 7 8 9

68

Brain Tissue Oxygen (PbtO2 or PtiO2)

Round 1: Median [IQR] 7 [6-8]

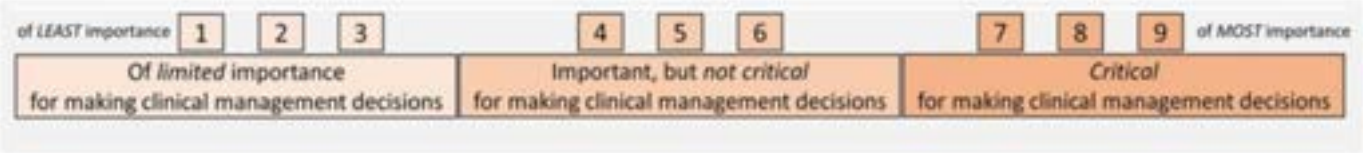


1 2 3 4 5 6 7 8 9

69

Jugular Venous Oxygen (SjvO2)

Round 1: Median [IQR] 4 [3-6]

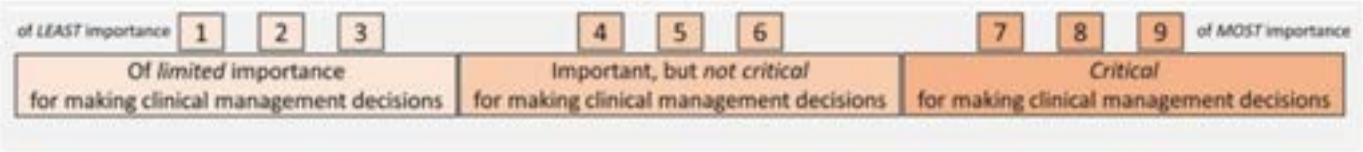


1 2 3 4 5 6 7 8 9

70

Regional Oxygen Saturation (rSO2) using Near-Infrared Spectroscopy (NIRES) or other optical imaging technology

Round 1: Median [IQR] 4.5 [3-6]

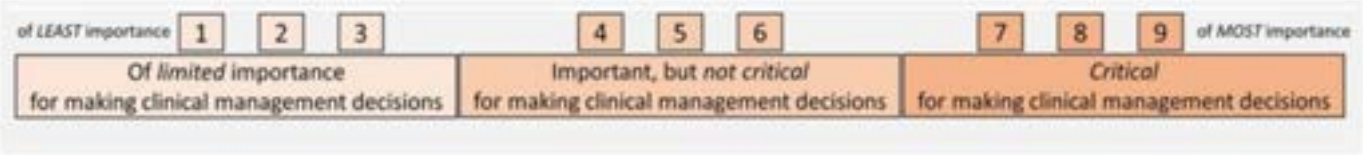


1 2 3 4 5 6 7 8 9

71

Regional Cerebral Blood Flow (rCBF)

Round 1: Median [IQR] 5 [5-6.75]



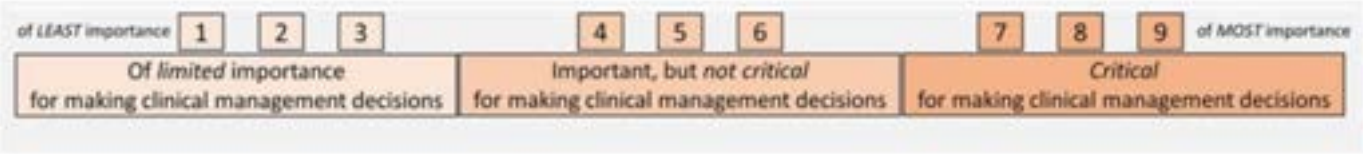
1 2 3 4 5 6 7 8 9

○ ○ ○ ○ ○ ○ ○ ○ ○

72

Brain Temperature

Round 1: Median [IQR] 6 [5-7]



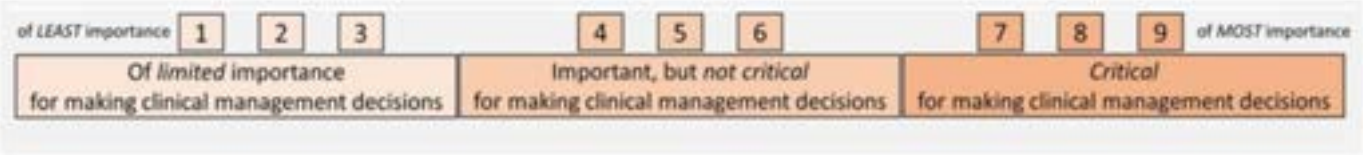
1 2 3 4 5 6 7 8 9

○ ○ ○ ○ ○ ○ ○ ○ ○

73

Brain Water Constant (K)

Round 1: Median [IQR] 4 [2-5]

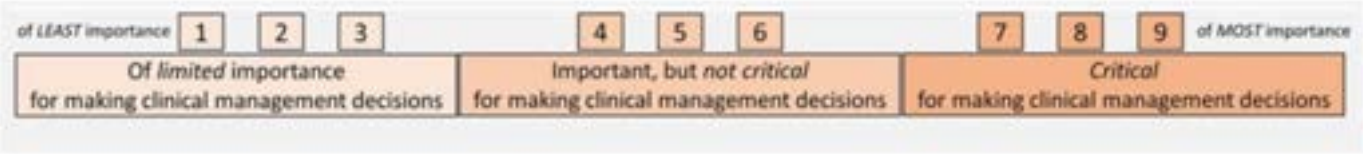


1 2 3 4 5 6 7 8 9

74

Cerebral Microdialysis: Lactate & Pyruvate

Round 1: Median [IQR] 6 [5-7]

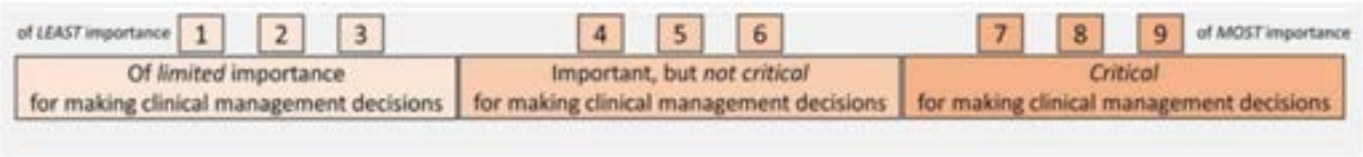


1 2 3 4 5 6 7 8 9

75

Cerebral Microdialysis: Brain Tissue Glucose

Round 1: Median [IQR] 6 [5-7]

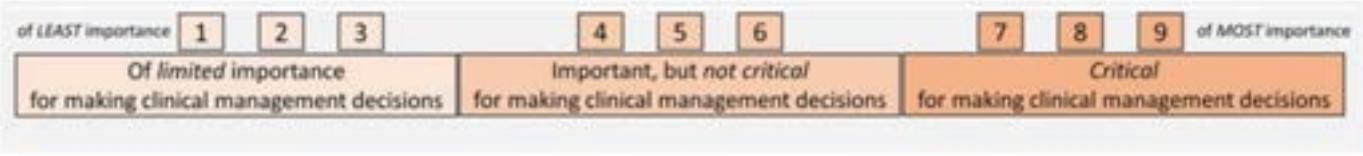


1 2 3 4 5 6 7 8 9

76

Cerebral Microdialysis: Glutamate

Round 1: Median [IQR] 5 [2.25-6]

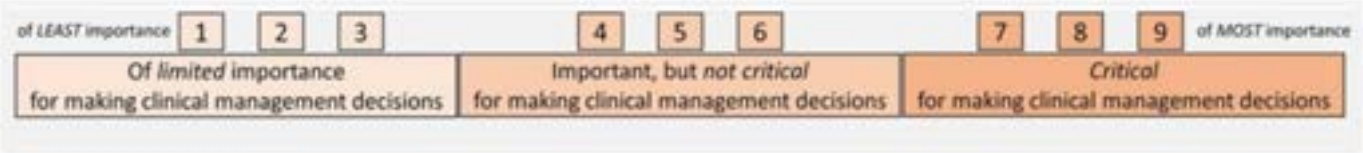


1 2 3 4 5 6 7 8 9

77

Cerebral Microdialysis: Glycerol

Round 1: Median [IQR] 4.5 [2-6]

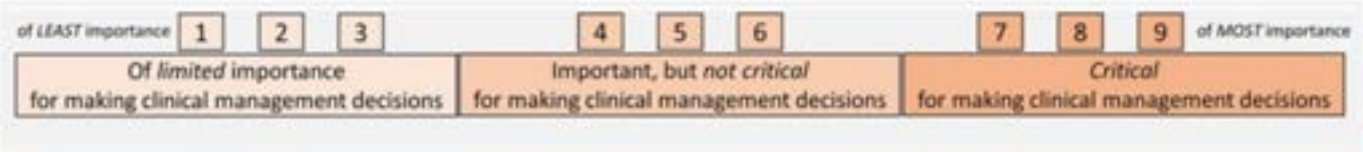


1 2 3 4 5 6 7 8 9

78

Continuous Scalp EEG

Round 1: Median [IQR] 8 [7-9]

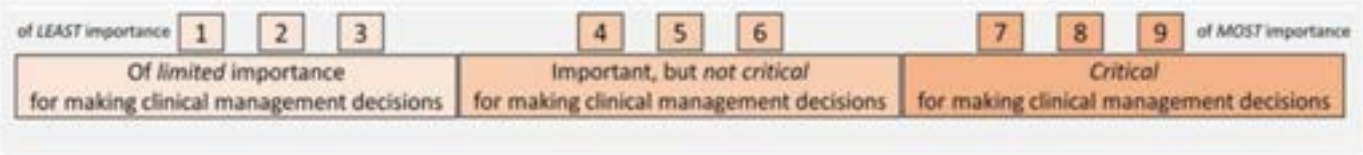


1 2 3 4 5 6 7 8 9

79

Electrocorticography: Single-wire or Depth Electrode

Round 1: Median [IQR] 5 [3-6]

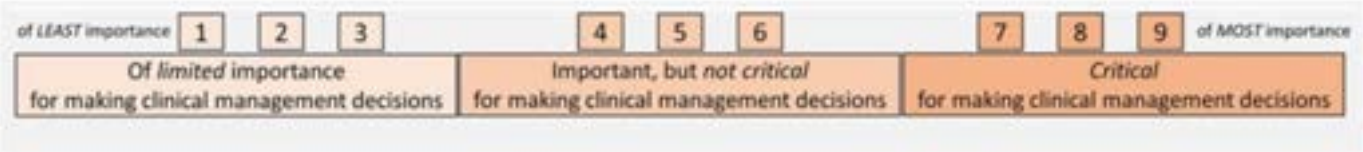


1 2 3 4 5 6 7 8 9

80

Electrocorticography: Strip Electrode

Round 1: Median [IQR] 5 [3-6]

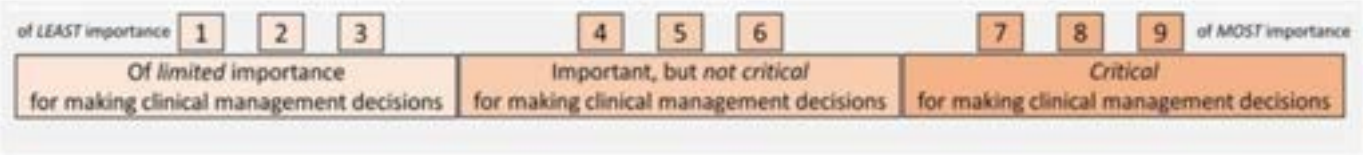


1 2 3 4 5 6 7 8 9

81

Full-band (DC or near-DC) EEG Recordings

Round 1: Median [IQR] 5 [3-6]

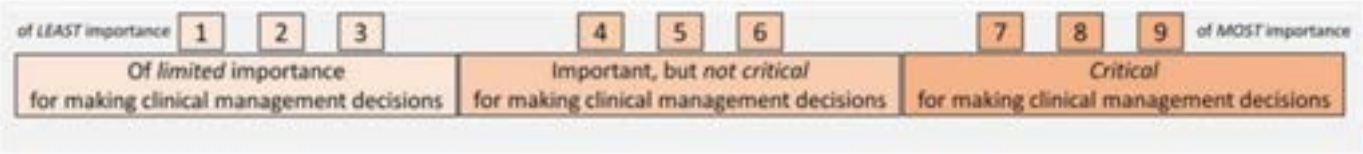


1 2 3 4 5 6 7 8 9

82

Quantitative EEG

Round 1: Median [IQR] 7 [5.25-8]



1 2 3 4 5 6 7 8 9

83

Processed EEG Indices of Anesthesia/Sedation Depth

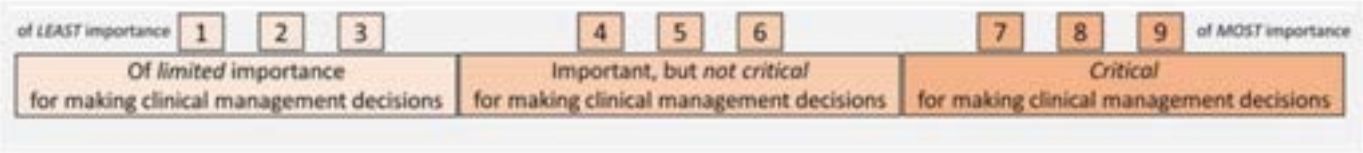
Round 1: Median [IQR] 5 [2.25-6]

1 2 3 4 5 6 7 8 9

84

Quantitative Pupillometry

Round 1: Median [IQR] 7 [5-9]

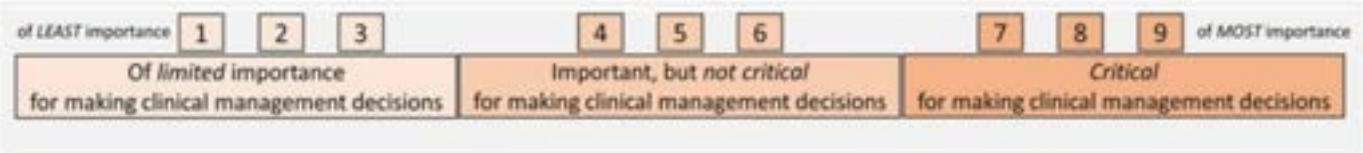


1 2 3 4 5 6 7 8 9

85

Extended-Duration (> 30 min) or Frequent (> 1 daily) Transcranial Doppler Ultrasonography

Round 1: Median [IQR] 4 [3-6]



1 2 3 4 5 6 7 8 9

86

Autonomic Function (e.g. heart rate variability)

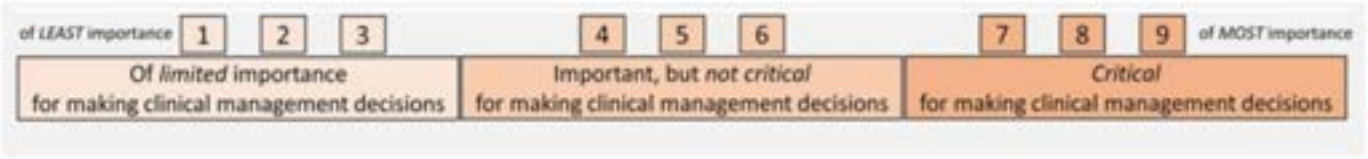
Round 1: Median [IQR] 3 [3-5]

1 2 3 4 5 6 7 8 9

87

Arterial Blood Pressure (ABP)

Round 1: Median [IQR] 9 [8.25-9]

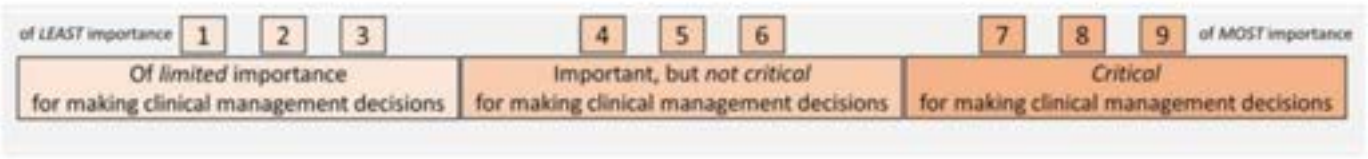


1 2 3 4 5 6 7 8 9

88

Cardiac Telemetry (ECG)

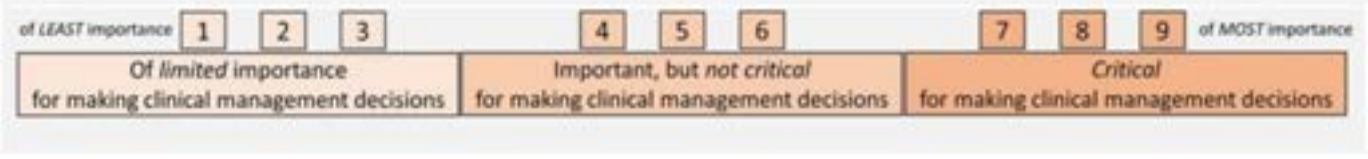
Round 1: Median [IQR] 9 [7-9]



1 2 3 4 5 6 7 8 9

89

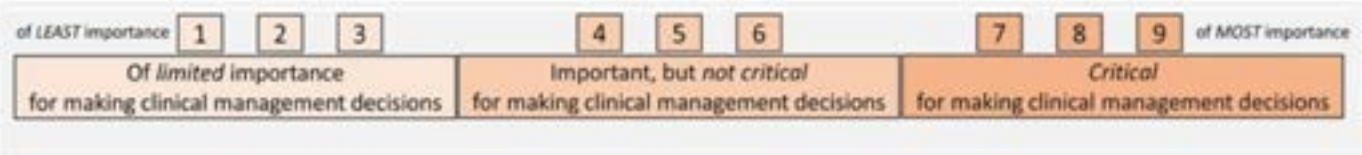
New Question
Plethysmography (SpO2)



1 2 3 4 5 6 7 8 9

Continuous Core Body Temperature or Continuous Water Temperature (in patients undergoing targeted temperature management)

Round 1: Median [IQR] 8.5 [7-9]



1 2 3 4 5 6 7 8 9

Minimum Necessary Technology: Access

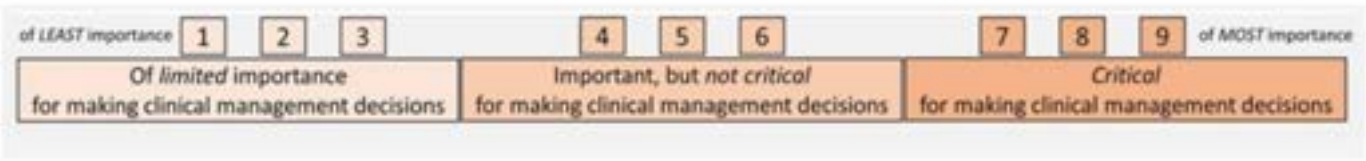
How important are each of the following to the use of neuromonitoring data to make care decisions?

If you have no personal experience accessing neuromonitoring data as described below, answer to the best of your abilities based on your existing expertise.

91

Bedside visualization or display of a *single*, current (live) measurement value, e.g. a single numeric value displayed on a device at that moment in time visible in a patient care area.

Round 1: Median [IQR] 8 [5-9]

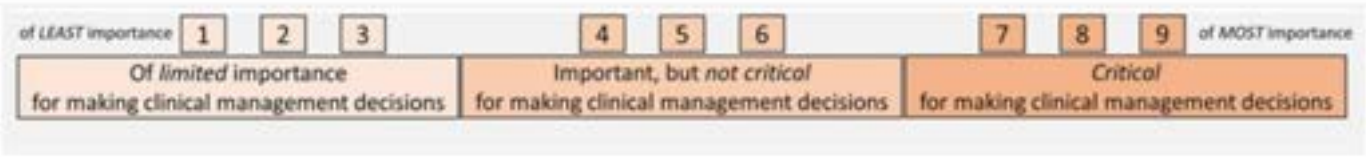


1 2 3 4 5 6 7 8 9

92

Bedside visualization or display of *single* measurement trended over time, e.g. a graph of a time-series displayed on a device visible in a patient care area.

Round 1: Median [IQR] 8 [7-9]



1 2 3 4 5 6 7 8 9

93

Bedside visualization or display of *multiple*, current (live) measurement values together on the same screen, e.g. multiple numeric measurement values from different devices displayed on the same screen and visible in a patient care area.

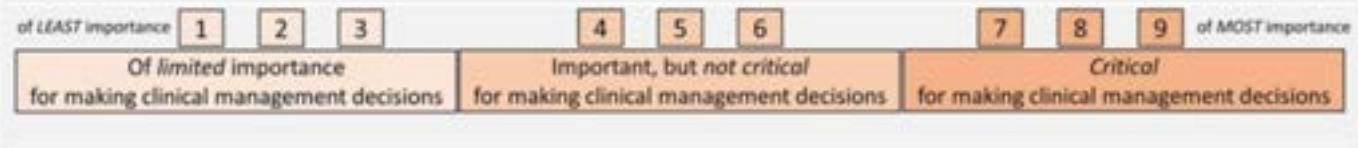
Round 1: Median [IQR] 8 [6.25-9]

1 2 3 4 5 6 7 8 9

94

Bedside visualization or display of *multiple* measurements trended over time and aligned on the same screen, e.g. a graph of several time-series from different devices displayed on the same screen and visible in a patient care area.

Round 1: Median [IQR] 9 [7-9]

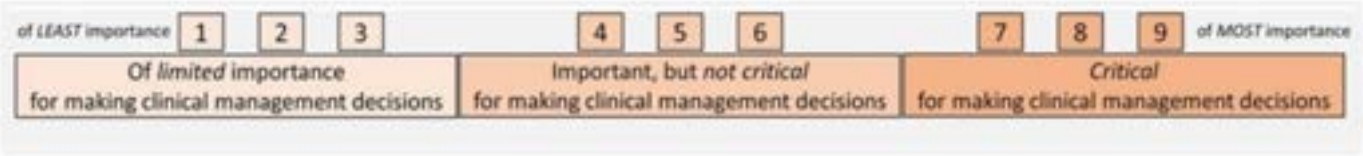


1 2 3 4 5 6 7 8 9

95

New Question

Bedside visualization or display of summary or aggregate data such as "Area Under the Curve", "Burden" or "Dose" on a device visible in a patient care area.

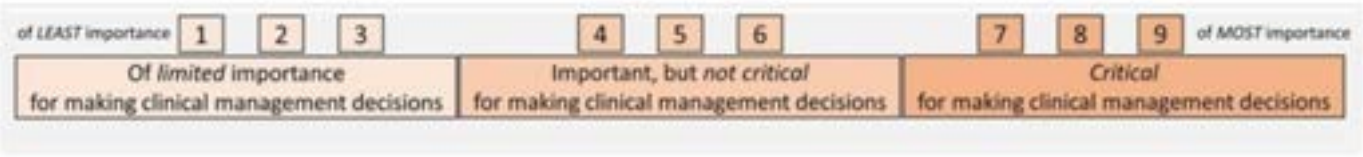


1 2 3 4 5 6 7 8 9

96

Access to data with high temporal resolution (1 or more data points every minute) including clinically-standard data such as heart rate, arterial blood pressure in addition to neuromonitoring-specific data.

Round 1: Median [IQR] 7 [7-9]

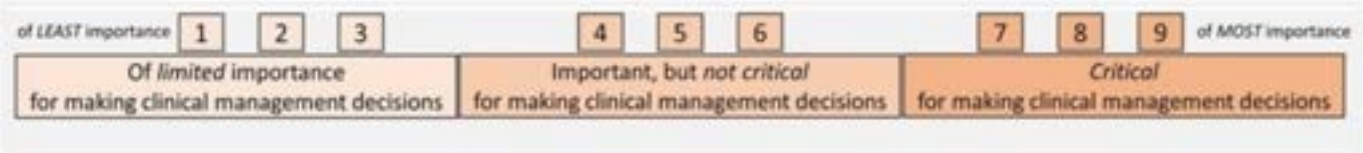


1 2 3 4 5 6 7 8 9

97

Access to data at waveform resolution, such as ECG waveforms, arterial blood pressure or intracranial pressure waveforms, or EEG signals.

Round 1: Median [IQR] 7.5 [7-9]

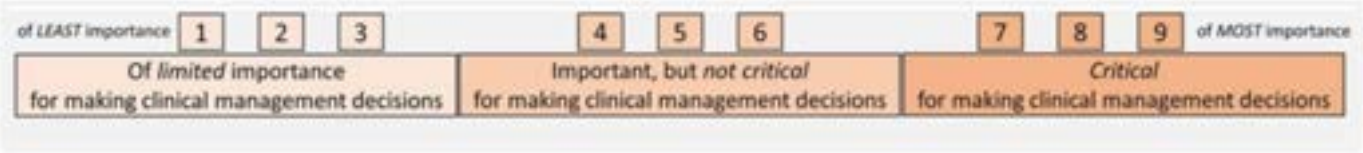


1 2 3 4 5 6 7 8 9

98

Integration with the Electronic Health Record through capture of *single* measurement values, e.g. within flowsheet rows or tables.

Round 1: Median [IQR] 7 [5.25-9]



1 2 3 4 5 6 7 8 9

99

Integration with the Electronic Health Record through display (in a table or graph) of *multiple* different measurement values together on a single panel, tab, or screen.

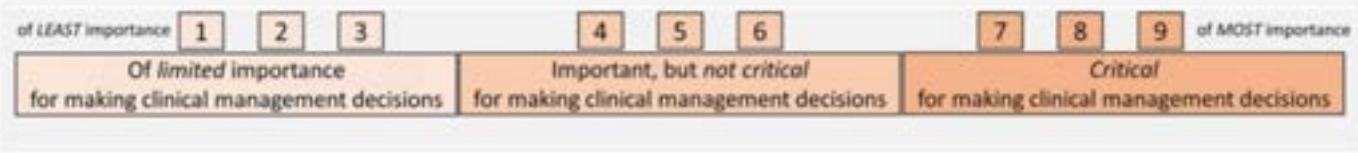
Round 1: Median [IQR] 8 [6-9]

1 2 3 4 5 6 7 8 9

100

Ability to manipulate data visualization or display AT BEDSIDE, e.g. zooming in or out (time scaling), scrolling back and forth in time, or selecting which neuromonitoring measurements to display.

Round 1: Median [IQR] 7 [7-9]

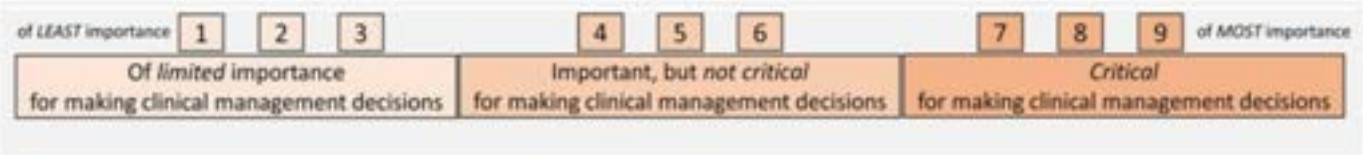


1 2 3 4 5 6 7 8 9

101

Ability to annotate neuromonitoring data AT BEDSIDE to indicate clinical events or other contextual data.

Round 1: Median [IQR] 8 [7-9]



1 2 3 4 5 6 7 8 9

102

Ability to display neuromonitoring data AT BEDSIDE linked with annotations to indicate clinical events or other contextual data.

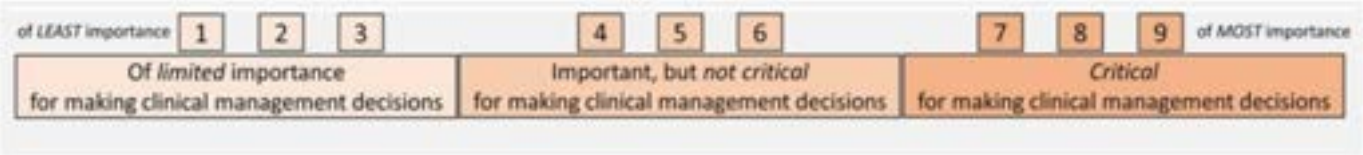
Round 1: Median [IQR] 8 [6.25-9]

1 2 3 4 5 6 7 8 9

103

Ability to display neuromonitoring data AT BEDSIDE linked with Electronic Health Record information, e.g. laboratory values or medication administration information.

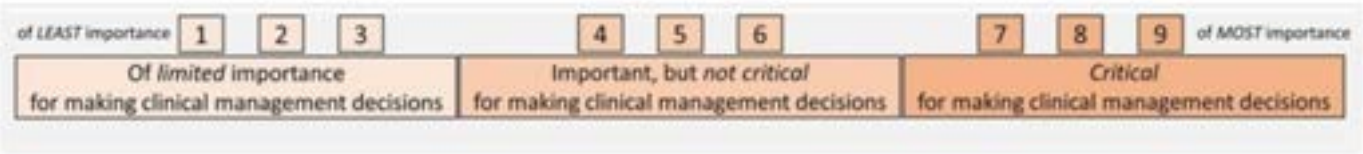
Round 1: Median [IQR] 7 [6-8]



1 2 3 4 5 6 7 8 9

104

New Question
Ability to display therapeutic decision-making aids, decision support tools or diagnostic/management algorithms for clinical staff AT BEDSIDE, e.g. interactive prompts or step-wise clinical guidance.

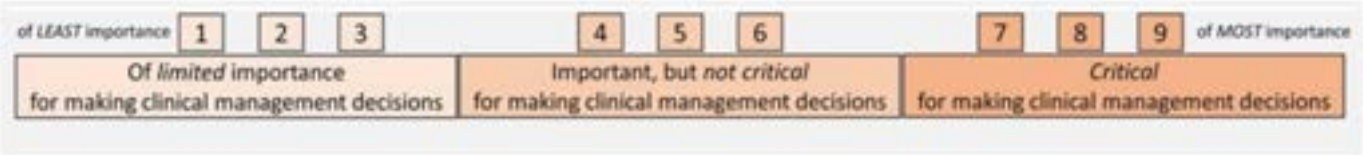


1 2 3 4 5 6 7 8 9

105

Ability to visualize or display neuromonitoring data in real-time REMOTELY (from a separate reading room or from home).

Round 1: Median [IQR] 8 [7-9]

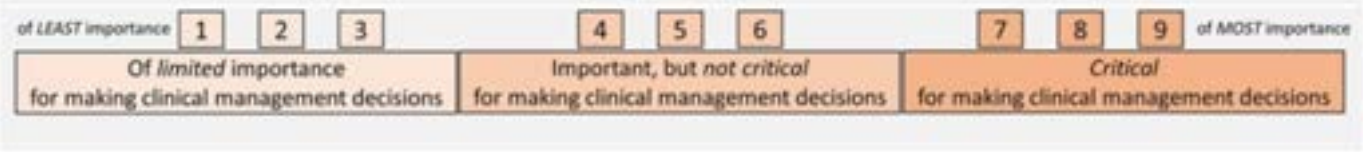


1 2 3 4 5 6 7 8 9

106

Ability to manipulate and review displayed neuromonitoring data in real-time REMOTELY (from a separate reading room or from home), e.g. choosing specific neuromonitoring measurements to display or zooming in or out of the data.

Round 1: Median [IQR] 8 [7-9]

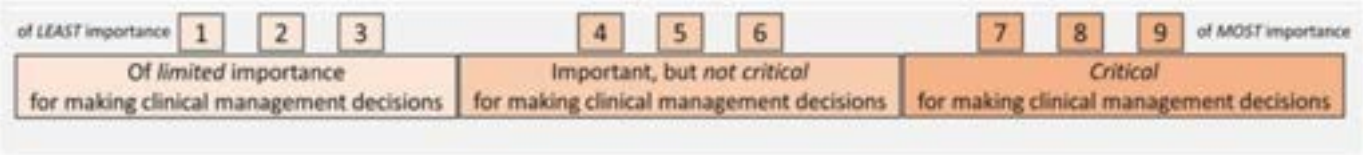


1 2 3 4 5 6 7 8 9

107

Ability to annotate neuromonitoring data REMOTELY to indicate clinical events or other contextual data.

Round 1: Median [IQR] 7 [5.25-9]

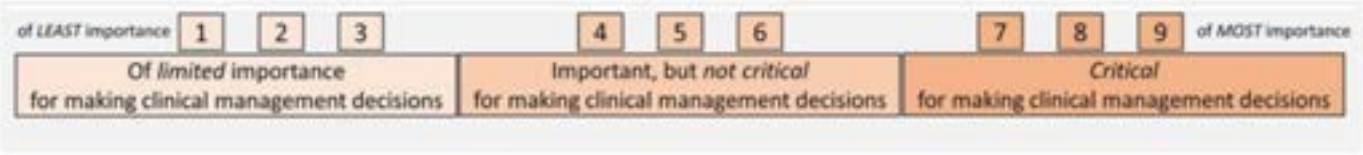


1 2 3 4 5 6 7 8 9

108

Ability to display neuromonitoring data REMOTELY linked with bedside annotations that indicate clinical events or other contextual data.

Round 1: Median [IQR] 7 [6-9]

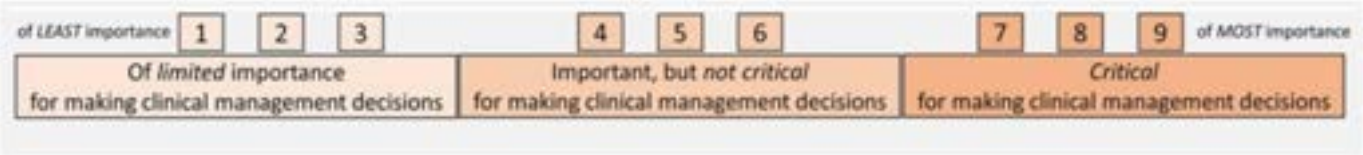


1 2 3 4 5 6 7 8 9

109

Ability to display neuromonitoring data REMOTELY linked with Electronic Health Record information, e.g. laboratory values or medication administration information.

Round 1: Median [IQR] 7 [6-9]

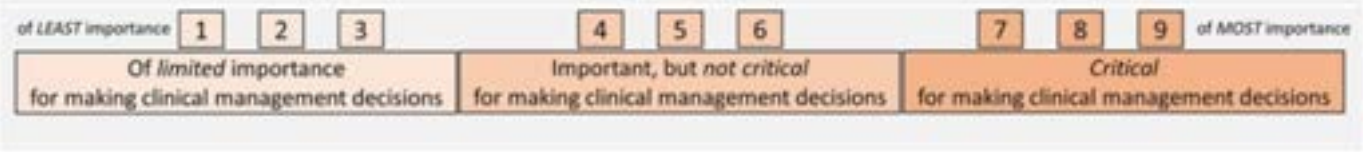


1 2 3 4 5 6 7 8 9

110

Ability to access neuromonitoring data for use in other software packages (e.g. Excel or R) by downloading from a hardware interface (e.g. bedside download of data through a USB drive).

Round 1: Median [IQR] 5.5 [3-8]



1 2 3 4 5 6 7 8 9

111

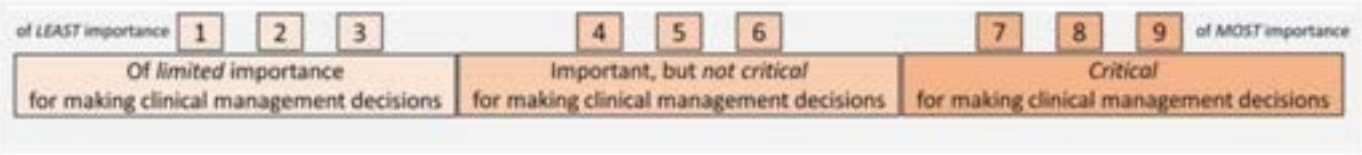
Ability to access neuromonitoring data for use in other software packages (e.g. Excel or R) through software or server-based interface, e.g. data is accessible from a server.

Round 1: Median [IQR] 7 [3-8]

1 2 3 4 5 6 7 8 9

112

New Question
Ability to access neuromonitoring data in REAL-TIME for use in data analytic tools (e.g. ICM+ or Persyst) either through a network interface or hardware connection.

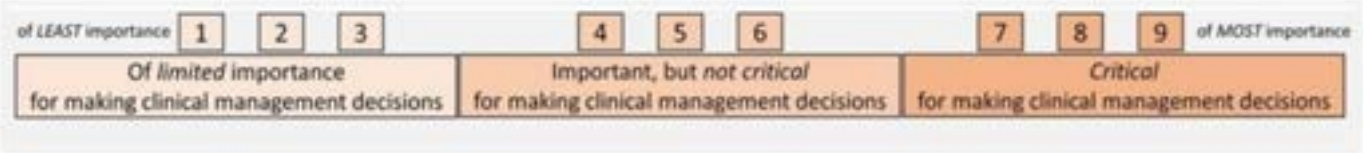


1 2 3 4 5 6 7 8 9

113

New Question

Ability to access neuromonitoring data in REAL-TIME for use in a secure cloud-based platform capable of deploying data analytic tools (e.g. machine learning algorithms).



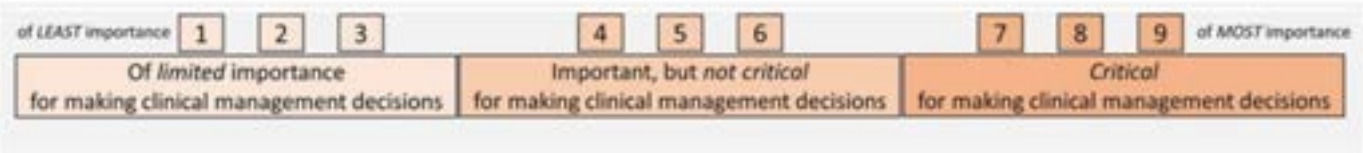
1 2 3 4 5 6 7 8 9

114

Ability to set alarms or thresholds to alert staff AT BEDSIDE, e.g. via flashing colors or alarm sounds.

Round 1: Median [IQR] 7 [6-8.75]

N.B. alarms or thresholds may be based on single or multiple parameters

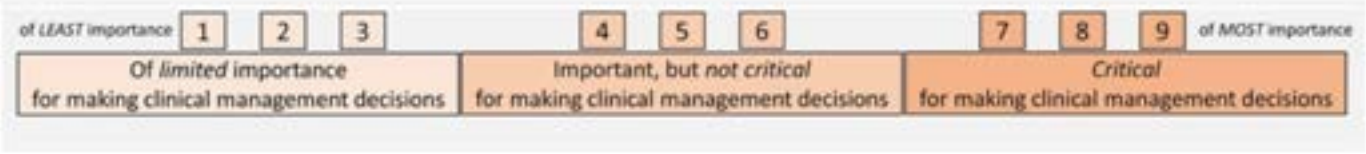


1 2 3 4 5 6 7 8 9

Ability to set alarms or thresholds to alert staff REMOTELY, e.g. through push notifications or email.

Round 1: Median [IQR] 6 [4.25-8]

N.B. alarms or thresholds may be based on single or multiple parameters



1 2 3 4 5 6 7 8 9

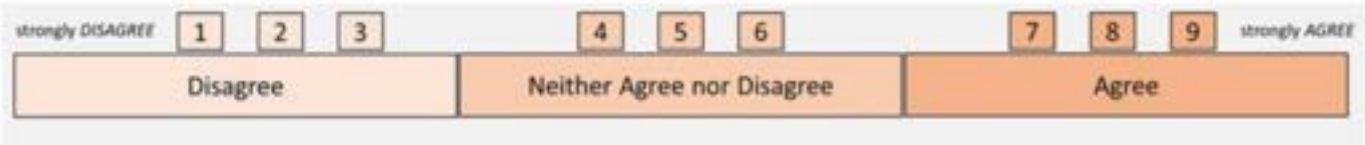
Minimum Necessary Work: Agree or Disagree

For the following questions, indicate the level of agreement about the following statements.

116

I feel that most intensivists staffing an ICU and caring for patients with brain injuries are able to adequately INTEGRATE AND INTERPRET multimodality neuromonitoring data as part of daily clinical care in order to make management decisions.

Round 1: Median [IQR] 3 [2-4]

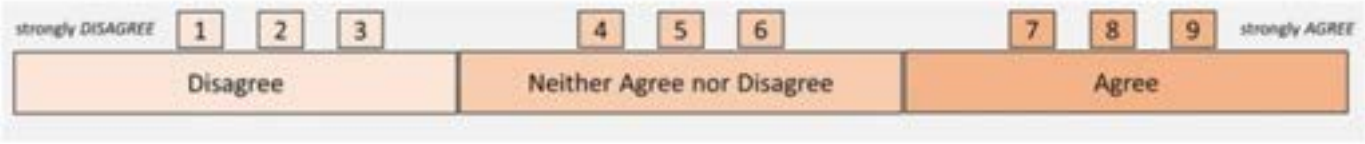


1 2 3 4 5 6 7 8 9

117

I feel that most intensivists staffing an ICU and caring for patients with brain injuries have adequate TIME to fully review all available multimodality neuromonitoring data as part of daily clinical care.

Round 1: Median [IQR] 3 [2-3]

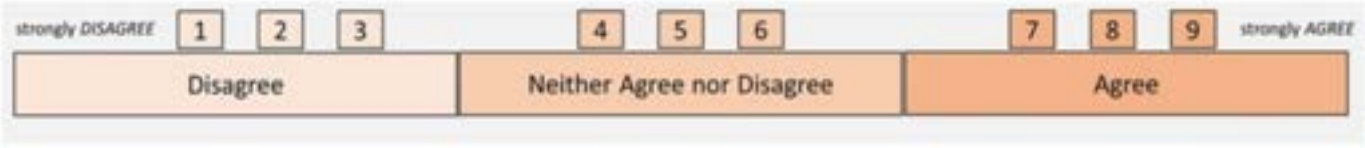


1 2 3 4 5 6 7 8 9

118

I feel that most intensivists staffing an ICU and caring for patients with brain injuries have all the necessary TECHNOLOGY to integrate and interpret multimodality neuromonitoring data as part of daily clinical care.

Round 1: Median [IQR] 2 [1-3]

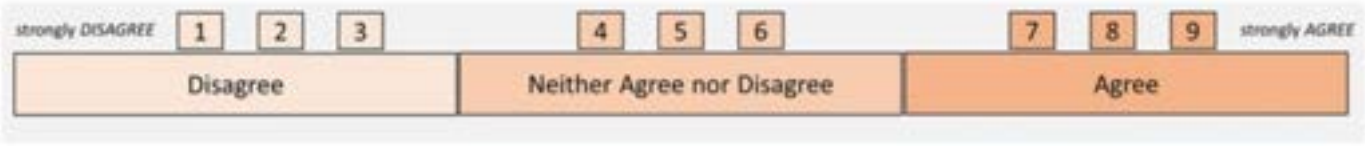


1 2 3 4 5 6 7 8 9

119

I feel that most intensivists staffing an ICU and caring for patients with brain injuries have TECHNICAL KNOWLEDGE sufficient to troubleshoot device errors and to identify artifactual or erroneous multimodality neuromonitoring data.

Round 1: Median [IQR] 2 [1-3]

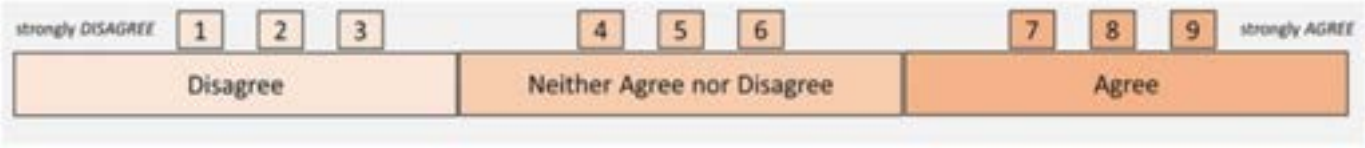


1 2 3 4 5 6 7 8 9

120

I feel that most intensivists staffing an ICU and caring for patients with brain injuries have CLINCAL KNOWLEDGE of brain physiology sufficient to use multimodality neuromonitoring data in making clinical decisions as part of daily clinical care.

Round 1: Median [IQR] 5 [3-6]



1 2 3 4 5 6 7 8 9

121

I feel most intensivists staffing an ICU and caring for patients with brain injuries would find regularly written reports summarizing multimodality neuromonitoring data and providing clinical interpretation/correlation to be helpful in making clinical decisions as part of daily clinical care.

Round 1: Median [IQR] 7.5 [7-9]

1 2 3 4 5 6 7 8 9

122

I feel that the INTEGRATION AND INTERPRETATION of multimodality neuromonitoring requires access to raw data for data manipulation outside of the devices on which data is measured, e.g. for pre-processing/cleaning, aggregation, integration with other data, computational analytics, and/or statistical analysis.

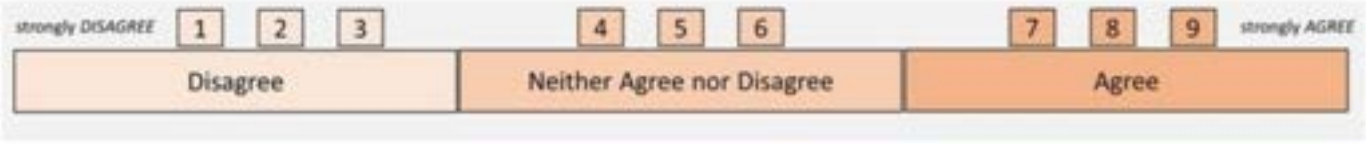
Round 1: Median [IQR] 8 [7-9]

1 2 3 4 5 6 7 8 9

123

I feel that the INTEGRATION AND INTERPRETATION of multimodality neuromonitoring data requires review of a variety of time-scales - from hours to days of data - in order to make clinically-meaningful inferences from the information.

Round 1: Median [IQR] 8.5 [8-9]



1 2 3 4 5 6 7 8 9

124

New Question

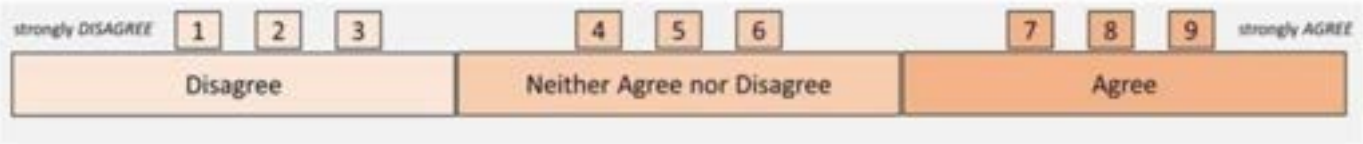
I feel that the INTEGRATION AND INTERPRETATION of multimodality neuromonitoring data is part of neurocritical care and <u>is NOT distinct</u> from the work of either critical care or general clinical duties as it exists currently.

1	2	3	4	5	6	7	8	9
○	○	○	○	○	○	○	○	○

125

New Question

I feel that the INTEGRATION AND INTERPRETATION of multimodality neuromonitoring data is part of neurocritical care and <u>would NOT be distinct</u> from the work of either critical care or general clinical duties *if* a simplified user interface is provided for bedside users without expertise and/or experience.



1	2	3	4	5	6	7	8	9
○	○	○	○	○	○	○	○	○

126

New Question

I feel that the INTEGRATION AND INTERPRETATION of multimodality neuromonitoring requires specific skill or expertise to synthesize multiple data trends over time that reflect disease trajectory.

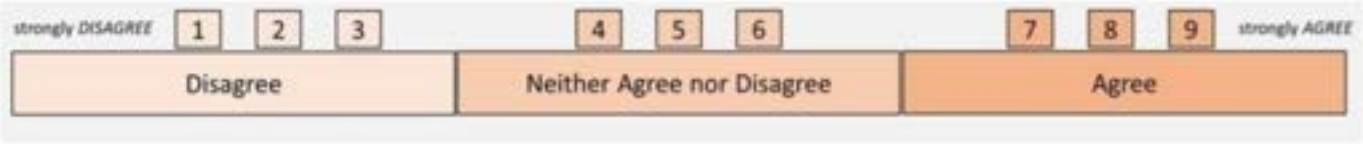
1 2 3 4 5 6 7 8 9

○ ○ ○ ○ ○ ○ ○ ○ ○

127

New Question

I feel that the INTEGRATION AND INTERPRETATION of multimodality neuromonitoring requires skill or expertise that is NOT routinely developed by any single fellowship training programs that exist currently.



1 2 3 4 5 6 7 8 9

○ ○ ○ ○ ○ ○ ○ ○ ○

128

New Question

I feel that the INTEGRATION AND INTERPRETATION of multimodality neuromonitoring requires integration with both brain-specific data *and* systemic data traditionally measured during critical care (e.g. hemodynamic information).

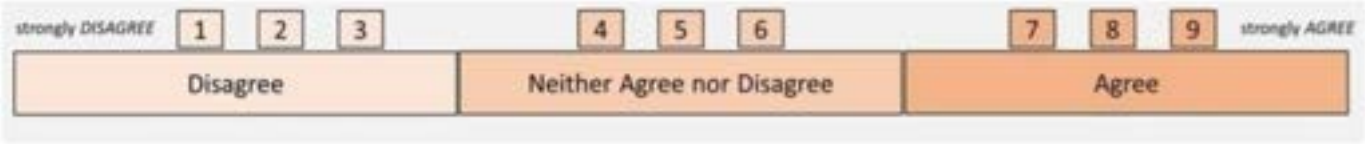
1 2 3 4 5 6 7 8 9

○ ○ ○ ○ ○ ○ ○ ○ ○

129

New Question

I feel that the INTEGRATION AND INTERPRETATION of multimodality neuromonitoring requires clinical context and that 'clinical correlation' is a central component of this process.



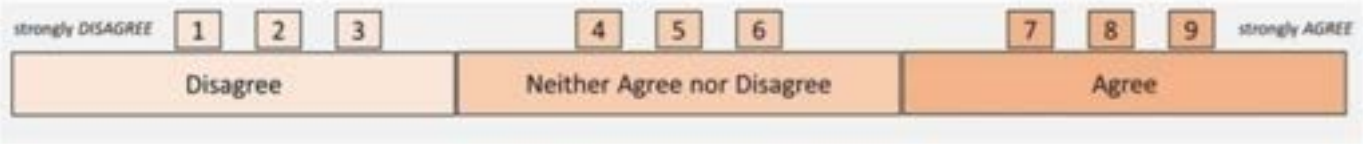
1 2 3 4 5 6 7 8 9

○ ○ ○ ○ ○ ○ ○ ○ ○

130

New Question

I feel that the APPLICATION AND MAINTENANCE OF EQUIPMENT AND TECHNOLOGIES related to multimodality neuromonitoring is time intensive for a clinician INDEPENDENT of other clinical duties.



1 2 3 4 5 6 7 8 9

131

New Question

I feel that the SYNTHESIS AND INTERPRETATION of multiple neuromonitoring data trends is time intensive for a clinician INDEPENDENT of other clinical duties.

1 2 3 4 5 6 7 8 9

132

New Question

I feel that existing billing codes for critical care (e.g. CPT 99291 or 99292) adequately capture the WORK of multimodality neuromonitoring.

N.B. if your practice exists in an area in which billing codes are not used to capture effort associated with clinical care, please leave this question blank

1 2 3 4 5 6 7 8 9

133

New Question

I feel that existing billing codes for other neurophysiologic procedures such as continuous video EEG monitoring (e.g. CPT 95720) or intraoperative monitoring (e.g. CPT 95941) adequately capture the WORK of multimodality neuromonitoring.

N.B. if your practice exists in an area in which billing codes are not used to capture effort associated with clinical care, please leave this question blank

1 2 3 4 5 6 7 8 9

New Section

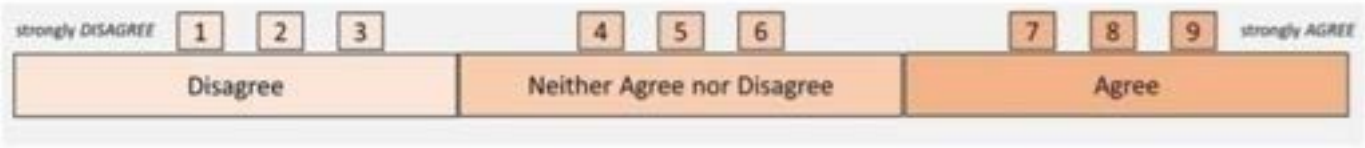
Operationalizing Multimodality Neuromonitoring: Agree or Disagree

Assume you are wanting to start or expand the use of comprehensive multimodality neuromonitoring at your institution. What elements would be helpful in order to move forward in operationalizing or implementing monitoring for patients with acute brain injuries?

For the following questions, indicate the level of agreement about the following statements.

134

I feel I can best operationalize multimodality neuromonitoring in my clinical practice now if I could provide for bedside users (e.g. clinical care team) an interface that facilitates an understanding of multiple parameters in the context of a specific disease process.



1 2 3 4 5 6 7 8 9

○ ○ ○ ○ ○ ○ ○ ○ ○

135

I feel I can best operationalize multimodality neuromonitoring in my clinical practice now if I could provide for bedside users (e.g. clinical care team) an interface that displays trend data on a single screen that can be used to manipulate and explore data.

1 2 3 4 5 6 7 8 9

○ ○ ○ ○ ○ ○ ○ ○ ○

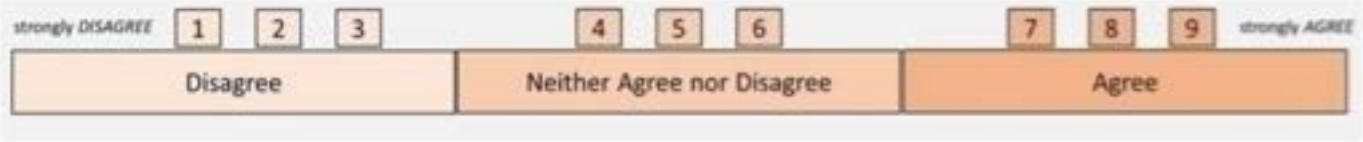
136

I feel I can best operationalize multimodality neuromonitoring in my clinical practice now if I had could enhance clinical confidence in our monitoring data by using software tools to identify or remove artifacts within real-time monitoring data that limits clinical interpretation by bedside users (e.g. clinical care team).

1 2 3 4 5 6 7 8 9

137

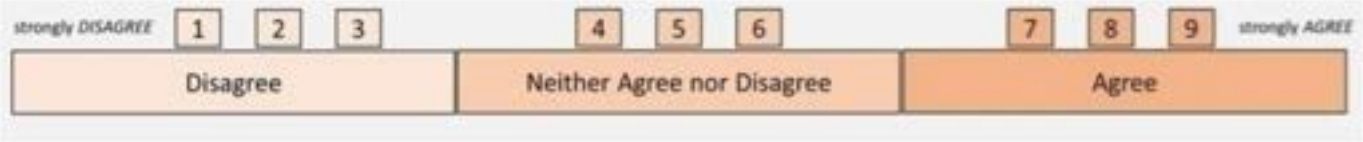
I feel I can best operationalize multimodality neuromonitoring in my clinical practice now if I had could enhance clinical confidence in our monitoring data by providing transparency for the methods used to derive calculations or summary statistics.



1 2 3 4 5 6 7 8 9

138

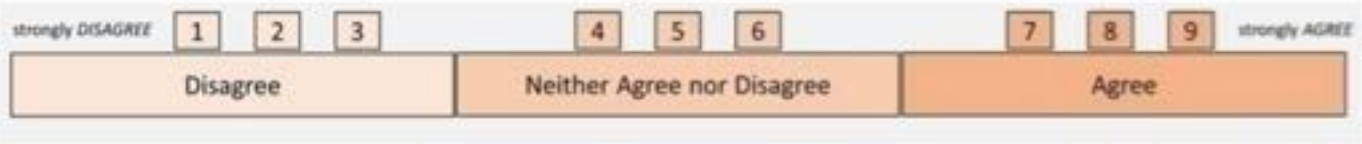
I feel I can best operationalize multimodality neuromonitoring in my clinical practice now if I could provide remote access to monitoring data for members of the clinical care team.



1 2 3 4 5 6 7 8 9

139

I feel I can best operationalize multimodality neuromonitoring in my clinical practice now if I could identify necessary Information Technology (IT) or Clinical Engineering personnel to overcome technological hurdles that limit access to monitoring data at my institution.



1 2 3 4 5 6 7 8 9

140

I feel I can best operationalize multimodality neuromonitoring in my clinical practice now if I invested in education for bedside users (e.g. clinical care team) focused on understanding the parameters being measured and why.

1 2 3 4 5 6 7 8 9

141

I feel I can best operationalize multimodality neuromonitoring in my clinical practice now if I invested in education for bedside users (e.g. clinical care team) focused on learning how to RESPONSD to monitoring data.

1 2 3 4 5 6 7 8 9

142

I feel I can best operationalize multimodality neuromonitoring in my clinical practice now if I disseminated existing evidence-based data and consensus-based care protocols to bedside users (e.g. clinical care team).

1 2 3 4 5 6 7 8 9

143

I feel I can best operationalize multimodality neuromonitoring in my clinical practice now if I were to standardize *WHO* is monitored and by *WHICH* technologies.

1 2 3 4 5 6 7 8 9

144

I feel I can best operationalize multimodality neuromonitoring in my clinical practice now if I were to develop clinical management algorithms based on patterns within monitoring data that can be identified by bedside users (e.g. clinical care team)

1 2 3 4 5 6 7 8 9

145

I feel I can best operationalize multimodality neuromonitoring in my clinical practice now if I could identify physiologic thresholds and other findings during monitoring that would mandate clinical action or trigger clinical judgement.

1 2 3 4 5 6 7 8 9

146

I feel I can best operationalize multimodality neuromonitoring in my clinical practice now if I had access to a standardized lexicon of patterns that occur in and between physiologic variables associated with specific underlying biology or clinical relevance.

1 2 3 4 5 6 7 8 9

147

I feel I can best operationalize multimodality neuromonitoring in my clinical practice now if I could enlist staff and/or trainees to provide expertise in the technical and clinical aspects of our monitoring devices at all times (including nights or weekends).

1 2 3 4 5 6 7 8 9

148

I feel I can best operationalize multimodality neuromonitoring in my clinical practice now if I could hire or enlist technologists, advanced practice providers and/or nursing educators to be available to provide expertise in the technical and clinical aspects of our monitoring devices at all times (including nights or weekends).

1 2 3 4 5 6 7 8 9

149

I feel I can best operationalize multimodality neuromonitoring in my clinical practice now if my institution could provide adequate time and support for a dedicated staff member to perform clinical interpretation of real-time monitoring data (e.g. a neuromonitoring 'reader').

1 2 3 4 5 6 7 8 9

150

I feel I can best operationalize multimodality neuromonitoring in my clinical practice now if a daily communication of information obtained from monitoring was made available either through notes in the Electronic Health Record or by sending emails to the clinical care team (e.g. neuromonitoring 'reports').

1 2 3 4 5 6 7 8 9

151

I feel I can best operationalize multimodality neuromonitoring in my clinical practice now if my institution had a staff member that acted as a 'clinical champion' to encourage the use of monitoring.

1 2 3 4 5 6 7 8 9

152

I feel I can best operationalize multimodality neuromonitoring in my clinical practice now if there was a CENTRALIZED expert reader through remote tele-health review of patients undergoing monitoring at my institution.

1 2 3 4 5 6 7 8 9

153

I feel I can best operationalize multimodality neuromonitoring in my clinical practice now if I were to directly engage the multiple stakeholders that are involved in the day-to-day care for patients undergoing monitoring, including neurocritical care, neurosurgery, neurology and others.

1 2 3 4 5 6 7 8 9

154

I feel I can best operationalize multimodality neuromonitoring in my clinical practice now if I scheduled regularly-held multidisciplinary case conferences to discuss relevant monitoring cases with others involved in day-to-day care for patients undergoing monitoring.

1 2 3 4 5 6 7 8 9

155

I feel I can best operationalize multimodality neuromonitoring in my clinical practice now by developing a business plan that financially incentivizes my hospital to invest in necessary capital expenditures.

1 2 3 4 5 6 7 8 9

156

I feel I can best operationalize multimodality neuromonitoring in my clinical practice now if there were a reimbursement strategy (e.g. a dedicated CPT code for neuromonitoring) to support dedicated clinicians to perform interpretation and reporting of monitoring data for use by clinical care teams in caring for patients with brain injuries.

1 2 3 4 5 6 7 8 9

New Section

Reporting Elements

For the following items, assume you are the attending physician for a care team caring for a patient with acute brain injuries. *Each day* you receive a report related to multimodality neuromonitoring. Which elements are important to make clinical decisions?

Assume data has been individualized and tailored to any physiologic measurements or modalities that you would find useful.

Select each reporting element you would find important *each day* as the attending physician responsible for a patient with acute brain injury undergoing multimodality neuromonitoring.

- [ ] Clinical Encounter Information (disease or injury mechanism, disease severity)
- [ ] Time since injury or onset of disease process
- [ ] Daily clinical information including clinical exam (GCS/NIHSS), medications of interest, continuous infusions and their ranges or trends, and relevant clinical events
- [ ] Data validity (e.g. artifacts, malfunction of specific modalities)
- [ ] Measurement values for each modality including summary statistics, # of "events" (such as ICP elevations or periods of brain hypoxia), "dose" (AUC) of insults
- [ ] Trends over time for each modality
- [ ] Inter-relationships between brain-specific measurements and hemodynamics
- [ ] Inter-relationships between brain-specific measurements and pulmonary function
- [ ] Inter-relationships between physiologic measurements and their changes in response to specific clinical events (e.g. treatment, medication administration, deterioration of neurologic examination)
- [ ] Identification of an optimum CPP and summary of autoregulatory information
- [ ] Synthesis of monitoring information: binary (e.g. present or absent) summary of specific "events" (e.g. 'seizures were present' or 'brain tissue hypoxia was not observed')
- [ ] Synthesis of monitoring information: phenomenologic interpretation or description of patterns that suggest particular pathology (e.g. 'the intracranial pressure correlated with arterial blood pressure suggesting dysfunction in autoregulation' or 'rising LPR and lower PbtO2 was seen suggesting developing ischemia')
- [ ] Synthesis of monitoring information: diagnostic interpretation (e.g. 'ischemia was flow-dependent and occurred during periods of hypotension' or 'brain tissue hypoxia was related to increased metabolic demand in the setting of frequent seizures')
- [ ] Identification of hypotheses for clinical care team to explore (e.g. 'brain tissue hypoxia may have responded to increases in peripheral oxygenation') and suggestions for goals of care (e.g. 'consider optimizing SpO2 to evaluate for a response in brain tissue oxygen')
- [ ] Description of significant CHANGES since prior reporting (e.g. 'Since the day prior, there is increasing brain tissue hypoxia')

- [ ] Predictions or probability assessments for adverse events (e.g. ICP crises or brain tissue hypoxia) to occur over the next 24-hr period

Training Standards: Agree or Disagree

For the following questions, indicate the level of agreement about the following statements.

158

I feel that specific training or expertise is required to adequately prepare clinicians to understand and interpret multimodality neuromonitoring information.

Round 1: Median [IQR] 8 [7-9]

1 2 3 4 5 6 7 8 9

159

I feel that clinical training programs in the neurological specialties (e.g. neurocritical care or neurophysiology) provide a knowledge base that adequately prepares clinicians to understand and interpret multimodality neuromonitoring information.

Round 1: Median [IQR] 5.5 [3.25-7]

1 2 3 4 5 6 7 8 9

160

I feel that clinical training programs in anesthesia and/or intensive care provide a knowledge base that adequately prepares clinicians to understand and interpret multimodality neuromonitoring information.

Round 1: Median [IQR] 6 [3.25-6.75]

1 2 3 4 5 6 7 8 9

161

New Question

I feel that clinical training programs in neurosurgery provide a knowledge base that adequately prepares clinicians to understand and interpret multimodality neuromonitoring information.

1 2 3 4 5 6 7 8 9

162

New Question

I feel that clinical training programs in emergency medicine provide a knowledge base that adequately prepares clinicians to understand and interpret multimodality neuromonitoring information.

1 2 3 4 5 6 7 8 9

163

New Question

I feel that clinical training programs in specialty nursing provide a knowledge base that adequately prepares clinicians to understand and interpret multimodality neuromonitoring information

1 2 3 4 5 6 7 8 9

164

I feel that ALL clinical training programs for practitioners who will be taking care of brain injured patients should provide education dedicated specifically to understanding the technical and clinical aspects of multimodality neuromonitoring.

Round 1: Median [IQR] 8 [7-9]

1 2 3 4 5 6 7 8 9

165

I feel that ONLY clinical training programs at centers that regularly use multimodality neuromonitoring should provide education dedicated specifically to understanding the technical and clinical aspects of multimodality neuromonitoring.

Round 1: Median [IQR] 5 [2.25-7]

1 2 3 4 5 6 7 8 9

166

New Question

I feel that an adequate knowledge base to understand and interpret multimodality neuromonitoring information DOES NOT require additional training in clinical neurophysiology or EEG regardless of primary specialty training.

1 2 3 4 5 6 7 8 9

167

New Question

I feel that an adequate knowledge base to understand and interpret multimodality neuromonitoring information DOES require additional training in clinical neurophysiology or EEG regardless of primary specialty training.

1 2 3 4 5 6 7 8 9

168

New Question

I feel that an adequate knowledge base to understand and interpret multimodality neuromonitoring information requires additional training in data management or health informatics.

1 2 3 4 5 6 7 8 9

169

New Question

I feel that an adequate knowledge base to understand and interpret multimodality neuromonitoring information requires additional training in bioengineering, signal analysis, or time-series analysis

1 2 3 4 5 6 7 8 9

New Section

Core Training Concepts

Consider you are developing a core training curriculum for multimodality neuromonitoring. Which core concepts are important?

170

Select each core concept you feel is critically important for a clinician to have an adequate knowledge base for understanding and interpreting multimodality neuromonitoring information.

- [ ] Critical care of patients undergoing monitoring
- [ ] Cerebral physiology (e.g. cerebral hemodynamics and autoregulatory function, ischemia, tissue hypoxia, intracranial compliance)
- [ ] Cellular physiology including concepts underlying energy metabolism, cell death, and the neurovascular unit
- [ ] Mechanics of monitoring devices (e.g. knowledge that a measurement of the partial pressure of oxygen is made by fiberoptic sensor) and pitfalls
- [ ] Technical aspects of monitoring devices (e.g. hardware connectivity, troubleshooting artifacts related to device malfunction)
- [ ] Existing evidence for the use and interpretation of multimodality neuromonitoring data
- [ ] Interactions between brain-specific data AND systemic data traditionally measured during critical care (e.g. hemodynamic information)
- [ ] Standard EEG analysis and interpretation, including recognition of seizures
- [ ] Full-band EEG analysis and interpretation, including recognition of both seizures and spreading depolarizations
- [ ] Methods for measuring autoregulation (e.g. moving average correlation coefficients between different parameters) and pitfalls
- [ ] Data management or health informatics
- [ ] Signal analysis and/or time-series analysis techniques

New Section

Educational Format: Agree or Disagree

For the following questions, indicate the level of agreement about the following statements.

171

I feel that training and expertise necessary to understand and interpret multimodality neuromonitoring is best acquired through SIMULATION or SIM-BASED LEARNING.

1 2 3 4 5 6 7 8 9

172

I feel that training and expertise necessary to understand and interpret multimodality neuromonitoring is best acquired through HANDS ON WORKSHOPS OR SEMINARS.

1 2 3 4 5 6 7 8 9

173

I feel that training and expertise necessary to understand and interpret multimodality neuromonitoring is best acquired through CLINICAL PRACTICE OR BEDSIDE TEACHING.

1 2 3 4 5 6 7 8 9

174

I feel that training and expertise necessary to understand and interpret multimodality neuromonitoring is best acquired through CASE-BASED LEARNING.

1 2 3 4 5 6 7 8 9

175

I feel that training and expertise necessary to understand and interpret multimodality neuromonitoring is best acquired through ONLINE, SELF-PACED MODULES.

1 2 3 4 5 6 7 8 9

176

I feel that training and expertise necessary to understand and interpret multimodality neuromonitoring is best acquired through MULTIDISCIPLINARY CASE CONFERENCES.

1 2 3 4 5 6 7 8 9

177

I feel that training and expertise necessary to understand and interpret multimodality neuromonitoring is best acquired through DEVELOPMENT OF A CORE CURRICULUM.

1 2 3 4 5 6 7 8 9

178

I feel that training and expertise necessary to understand and interpret multimodality neuromonitoring is best acquired through SUPERVISED PERFORMANCE and DEMONSTRATION OF PROCEDURAL COMPETANCY.

1 2 3 4 5 6 7 8 9

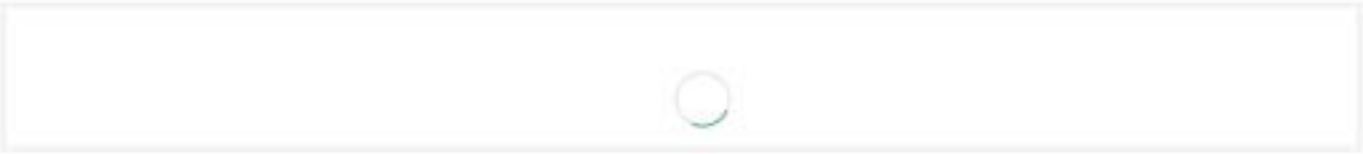
179

I feel that training and expertise necessary to understand and interpret multimodality neuromonitoring is best acquired through DEDICATED FELLOWSHIP TRAINING.

1 2 3 4 5 6 7 8 9

180

I feel that training and expertise necessary to understand and interpret multimodality neuromonitoring should be recognized through an online Certification process supported through collaborative partners interested in advancing neuromonitoring.



1 2 3 4 5 6 7 8 9

181

I feel that training and expertise necessary to understand and interpret multimodality neuromonitoring should be recognized through a Certification process supported through national societies (e.g. Neurocritical Care Society [NCS], American Clinical Neurophysiology Society [ACNS], or the American Society of Neurophysiologic Monitoring [ASNM]).

1 2 3 4 5 6 7 8 9

182

I feel that training and expertise necessary to understand and interpret multimodality neuromonitoring should be recognized through formal Board certification (e.g. through the United Council for Neurological Subspecialties or the American Board of Medical Specialties).

1 2 3 4 5 6 7 8 9