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REVIEW ARTICLE

International Multidisciplinary Consensus Conference on Multimodality Monitoring: ICU Processes of Care

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The Participants in the International Multidisciplinary Consensus Conference on Multimodality Monitoring

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Abstract There is an increased focus on evaluating processes of care, particularly in the high acuity and cost environment of intensive care. Evaluation of neurocritical-specific care and evidence-based protocol implementation are needed to effectively determine optimal processes of care and effect on patient outcomes. General quality measures to evaluate intensive care unit (ICU) processes of care have been proposed; however, applicability of these measures in neurocritical care populations has not been established. A comprehensive literature search was conducted for English language articles from 1990 to August 2013. A total of 1,061 articles were reviewed, with 145 meeting criteria for inclusion in this review. Care in specialized neurocritical care units or by neurocritical teams can have a positive impact on mortality, length of stay, and in some cases, functional outcome. Similarly, implementation of evidence-based protocol-directed care can enhance outcome in the neurocritical care population. There is significant evidence to support suggested quality indicators for the general ICU population, but limited research regarding specific use in neurocritical care. Quality indices for neurocritical care have been proposed; however, additional research is needed to further validate measures.

The Participants in the International Multidisciplinary Consensus Conference on Multimodality Monitoring are listed in "Appendix" section.

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Introduction

Evaluating processes of care are critical in the intensive care unit (ICU), where evaluation of monitoring and management of high-risk patients is paramount [1, 2]. Because safety, quality, and transparency are cornerstones of reimbursement, measures must determine how to deliver high quality, cost-effective care that optimizes patient outcomes [3–6]. In the ICU environment, measuring quality is a complex task, influenced by patient and family outcomes, work environment, and economic performance [7].

Quality traditionally includes structure, process, and outcome [7]. Structural indicators include the physical resources of the ICU environment, such as the presence of an ICU medical director, multidisciplinary daily rounds, and nurse/patient ratios [7]. Process indicators include protocols and best practice recommendations. Outcome measures encompass mortality and infection rates [7]. Various quality indicators to evaluate the effectiveness of ICU care have been proposed [1, 7–10]. With the emergence of multi-modality monitoring, neurocritical care and dedicated neurocritical care units (NCCU), there is a need to determine indices evaluating processes of care specific to neurocritical care.

Methods

An extensive librarian-and-investigator-led search was conducted using key words specific to quality indicators and processes in the ICU according to the Preferred

Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. The review period was between January 1980 and August 15, 2013 and was limited to clinical articles that included >5 subjects and were published in English. The focus was on adult patients with brain disorders. Articles were reviewed and evaluated using GRADE criteria.

Search Criteria

Key medical subject heading (MeSH) terms included "mortality", "length of stay", "multimodality monitoring","neurocritical care", "quality", "benchmarking", "ventilator associated pneumonia", "pressure ulcers", "blood stream infections", "glycemic control", and "protocol management".

Study Selection and Data Collection

The literature search resulted in 1,061 articles. Case reports, reviews, and infant/animal studies were excluded. There were 16 studies that specifically evaluated neurocritical care units or neurointensivist led teams and outcomes. An additional 129 articles addressed various quality indicators and processes of care, though not all were specific to solely to neurocritical care.

Review End-Points

Specific questions addressed included the following:

1. In critically ill patients with acute brain injury, how does care by a dedicated neurointensive care unit/team impact outcomes?
2. In the neurocritical care population, how does use of evidence-based protocols impact patient outcomes?
3. What are key quality indicators for ICU processes of care and are these applicable to the neurocritical care population?

Summary of the Literature

Dedicated Neurocritical Care

Numerous studies investigated the effect of a dedicated NCCU, neurocritical team, or neurointensivist on patient outcomes (Table 1). Most incorporated observational pre/post study designs to evaluate outcomes before and after implementation of a neurocritical care specialty. A recent systematic review [11] of 10 single-site observational studies [12–21] and 2 prospective multi-site studies [22, 23] of traumatic brain injury (TBI), aneurysmal subarachnoid hemorrhage (SAH), intracerebral hemorrhage (ICH), and acute ischemic stroke (AIS) indicate neurocritical care units or teams led by a neurointensivist experienced lower mortality and higher rates of "favorable outcome" [11]. While there was variation in neurocritical care structure, findings highlighted the positive impact of specialized neurocritical care on key quality outcomes [24–30]. Implementation of neurocritical care teams for aneurysmal SAH, ICH, and stroke increased likelihood of discharge to home [17, 24, 26], decreased likelihood to be discharged to a nursing home [25], resulted in better blood pressure control and dysphagia evaluations [30], and improved functional outcome, length of stay (LOS), and mortality [29]. A separate study evaluating risk prediction models and care location in TBI reported management in dedicated neurocritical care units compared to combined neuro/general critical care units may be more cost-effective and result in higher quality adjusted life years [31]. Additional studies that investigate the effect of high volume centers for TBI or SAH reported improved time to definitive treatment and GOS scores for centers that treat a large number of patients [32, 33]. However, exactly what constitutes "neurocritical care" e.g., a dedicated unit, specific protocol use, or an intensivist (or team) in a general ICU with expertise in neurologic disorders remains to be fully defined. In addition, whether the effect applies to all neurologic diseases and whether the relationship between neurocritical care and outcome is causal are still being elucidated.

Evidence-Based Protocols in Neurocritical Care

Implementation of evidence-based protocols may improve patient outcomes. Protocol effectiveness is maximized when combined with ongoing education and auditing throughout implementation and protocol evaluation [34, 35]. Many studies demonstrated effectiveness of evidence-based protocols in general ICU patient populations (Table 2).

In neurocritical care, the Brain Trauma Foundation (BTF) and the American Heart Association/American Stroke Association (AHA/ASA) have proposed guidelines [36–38]. A recent systematic review investigating the effectiveness of the BTF or similar protocol-directed guidelines in severe TBI included 13 prospective and retrospective observational studies, with sample sizes between 24 and 830 [39]. Cumulative findings indicate patients managed by protocols had decreased mortality at discharge and improved GOS Scores at 6 months [19, 20, 40–49]. Interventions included intracranial pressure (ICP)/cerebral perfusion pressure (CPP) protocol management groups, preprinted order forms, and brain volume regulation protocols.

Table 1 Evidence summary for specialized neurocritical care

Study	Design	N	Population	Findings
Warme [15]	Retrospective	121	TBI	Care in neuro-ICU resulted in decreased mortality and higher GOS scores
Diringer [22]	Analysis of prospective registry data	1,038	ICH	ICH patients in neurological or neurosurgical ICU had lower hospital mortality rate than ICH patients in general ICU; presence of full time intensivist associated with lower mortality rate
Mirski [14]	Retrospective	128	ICH	ICH patients in neuroscience ICU had lower mortality, and improved discharge disposition than ICH patients in general ICU. Neuroscience ICU patients had shorter hospital length of stay and lower costs than national benchmarks
Elf [19]	Retrospective	226	TBI	Care in neuro-ICU resulted in decreased mortality and improved functional outcome, measured by GOS scores
Patel [20]	Retrospective	285	TBI	Specialized neurointensive care resulted in decreased mortality and higher incidence of favorable outcome
Suarez [16]	Analysis of prospective registry data	2,381	Critically ill neuroscience patients	Decreased hospital mortality, shorter hospital and ICU length of stay after neurocritical care team was introduced
Varelas [13]	Observational cohort with historical controls	2,366	All NICU admissions	Decrease in mortality and length of stay, and improved discharge disposition after implementation of neurointensivist-led team
Varelas [25]	Retrospective	592	TBI	Decreased mortality and hospital length of stay, increased odds of discharge to home or rehabilitation after neurointensivist appointed
Lerch [18]	Retrospective	59	Aneurysmal SAH	Specialized neurocritical care associated with higher incidence of favorable outcome, measured by GOS
Bershad [26]	Retrospective	400	Acute ischemic stroke	Neurointensive care team associated with decreased ICU and hospital length of stay, and increased proportion of discharges home
Lott [23]	Prospective, multi-site	16,415	Intracranial hemorrage, ischemic stroke	Lower mortality and higher incidence of favorable outcome among units with neuro-specialized care
Josephson [12]	Retrospective	512	SAH	Neuro-intensivist co-management associated with decreased mortality
Palminteri [21]	Retrospective	287	ICH	No difference in mortality with neurointensivist; higher proportion of favorable outcome with neurointensivist-managed care
Samuels [17]	Retrospective	703	Aneurysmal subarachnoid hemorrhage	Patients treated by neurocritical care team more likely to receive definitive aneurysm treatment and be discharged home
Knopf [29]	Retrospective	2,096	AIS, ICH, aneurysmal SAH	Compared data prior to, during, and after departure of a neurointensivist (NI). For AIS, departure of the NI resulted in decreased functional outcome; for ICH, there was no effect of a NI, but shorter length of stay for patients in specialized neurocritical care unit, compared to a general ICU. For SAH, NI resulted in longer ICU LOS, but improved discharge disposition and mortality
Burns [30]	Retrospective	74	ICH	Introduction of a neurocritical care consult service resulted in more timely and sustained SBP control, and more dysphagia screens prior to initiation of oral feeding

Two separate prospective studies evaluated compliance with BTF guidelines and outcomes among patients with severe TBI, where patients were stratified by those receiving ICP monitoring or not [50, 51]. Compliance with BTF guidelines was 46 %. In one study, the ICP monitoring group experienced lower in hospital mortality, but longer ICU and hospital length of stay [50]. In the second study, compliance was not associated with mortality or unfavorable outcome [51].

Among stroke patients, research indicates transfer to a stroke center using AHA/ASA guidelines results in timely therapy and reduced morbidity and mortality [52, 53]. Recent guidelines for acute ischemic stroke have been published by the AHA/ASA [37], and data from both

Table 2 Evidence summary for protocol-directed care

Study	Design	*N*	Population	Findings
Elf [19]	Retrospective	154	TBI	Organized secondary insult management protocol and neurointensive care improved mortality rates and percentage of favorable outcome using GOS scores after 6 months
Patel [20]	Retrospective	285	TBI	Patients with severe head injury treated by ICP/CPP targeted protocol and neurocritical care specialists had higher percentage of favorable outcome measured by GOS scores 6 months post-injury
Arabi [40]	Retrospective/prospective	434	TBI	Implementation of protocol management based on BTF guidelines was associated with reduction in hospital and ICU mortality
Eker [41]	Prospective	91	TBI	Protocol targeting brain volume regulation and microcirculation reduced mortality and improved percentage of favorable outcome measured by GOS 6 months post-injury
McKinley [42]	Retrospective/prospective	24	TBI	ICP management protocol resulted in more consistent and improved ICP control, and less variation in CPP
Vukic [43]	Retrospective	39	TBI	Protocol based on BTF guidelines for ICP management resulted in decreased mortality and improved percentage of favorable GOS scale scores
McIlvoy [44]	Retrospective/prospective	125	TBI	BTF guidelines used to develop 4-phase protocol for ICP/CPP management, resulting in decreased hospital and ICU length of stay, decreased number of ventilator days and incidence of pneumonia, and earlier tracheostomy
Palmer [45]	Retrospective/prospective	93	TBI	BTF guideline implementation improved odds of good outcome, measured by GOS at 6 months
Vitaz [46]	Retrospective/prospective	162	TBI	Standardized clinical pathway for ICP/CPP management resulted in decreased hospital and unit length of stay and decreased ventilator days
Clayton [47]	Retrospective	669	TBI	CPP management protocol decreased ICU and hospital mortality, but had no effect on length of stay.
Fakhry [48]	Retrospective/prospective	830	TBI	Protocol developed from BTF guidelines decreased hospital length of stay and costs, and demonstrated a decreased trend in mortality and improved functional recovery
Cremer [49]	Retrospective/prospective	333	TBI	ICP/CPP targeted algorithm resulted in increased number of ventilator days and therapy intensity, with no difference in mortality when compared to supportive care control group
Talving [50]	Prospective	216	TBI	Observational study comparing patients managed with ICP monitoring vs. no monitoring and compliance with BTF guidelines. In hospital mortality higher in patients with no ICP monitoring. ICP monitoring group had longer ICU and hospital length of stay. BTF guideline compliance was 46.8 %
Biersteker [51]	Observational multi-site	265	TBI	Investigated compliance and outcomes of BTF guidelines for ICP monitoring. Guideline compliance was 46 %. Guideline compliance was not associated with mortality or unfavorable outcome when controlling for baseline and clinical characteristics
Meretoja [52]	Observational, multi-registry	61,685	AIS	Compared data from 333 hospitals classified as comprehensive stroke centers, primary stroke centers, and general hospitals. Mortality rates lower in stroke centers for up to 9 years
Smith [53]	Longitudinal cohort registry	6,223	AIS	Organized stroke care resulted in decreased 30 day mortality for each ischemic stroke subtype
Schwamm [54]	Prospective quality initiative	322, 847	AIS, TIA	Centers that participated in Get with the Guidelines-Stroke reported higher compliance with all stroke performance measures
Gropen [55]	Retrospective quality initiative	1,442	AIS	Designated stroke centers utilizing Brain Attack Coalition guidelines experienced shorter door to MD contact, CT scan time, and t-PA administration time

randomized controlled trials (RCTs) and observational studies support use of guidelines for transport to primary stroke centers [53–56]. Comprehensive stroke centers (CSC) have decreased mortality and severe disability and improved timely administration of tissue plasminogen activator (tPA) [52, 57, 58]. Guidelines from the AHA/ASA include admission to a specialized NCCU as a recommendation specifically for patients presenting with severe deficits, large infarcts, or significant comorbidities [37].

Quality Indicators for ICU Processes of Care

There is an abundance of literature on quality indicators for the general ICU patient population [1, 7–10]. Many indicators are reportable for all hospitalized patients, which include ventilator-associated pneumonia (VAP), central line associated blood stream infection (CLABSI), catheter-associated urinary tract infection (CAUTI), surgical site infections, length of stay, and ICU readmission within 48 h [6, 8]. Key quality measures routinely evaluated in general ICU patient populations include ventilator-associated pneumonia, pressure ulcers, blood stream infections (BSIs), and glycemic control. Whether these "general indicators" apply to neurocritical care or whether there are specific measures for neurocritical care is still being elucidated.

Ventilator-Associated Pneumonia

VAP rates range between 8 and 28 % among mechanically ventilated ICU patients and adversely affect patient mortality, length of stay, and hospital costs [59, 60]. Mortality rates for VAP range from 27 to 43 % [61]. VAP increases ICU LOS by 5–7 days [59], and hospital LOS by 2–3 days [62]. Estimated costs to treat VAP range from $9,000 to $40,000 per patient [63–65], totaling over 1.2 billion dollars per year [66].

The American Thoracic Society and the Infectious Diseases Society of America (ATS/IDSA) provide guidelines to manage VAP [67], and there is consistent evidence that strategies targeting primary pathophysiological mechanisms of VAP are effective, particularly when grouped into bundles [68–73]. While there is a variation in specific components of VAP bundles described in the literature, studies report decreased VAP incidence, particularly when audits are performed [74–79]. Protocol-driven weaning parameters also have been found to decrease VAP, number of ventilator days, and unplanned extubation rates [80–83].

However, within the neurocritical care, VAP rates are higher (21–68 %) than in general ICUs [79, 84, 85]. Diagnosis of VAP can be especially difficult in this population, where many patients experience field intubation or aspiration, resulting in pneumonia that is not truly ventilator-associated [72, 73, 86, 87]. Based on data from 20 ICUs in the United States, neurologic diagnoses accounted for 13.3 % of all VAP cases, second only to post-operative care (15.6 %). This was greater than the percentage of patients with a diagnosis of sepsis or cardiac complications who developed VAP [84]. Consistent with the general ICU literature, patients with TBI or stroke who experience VAP have greater hospital expenses, longer duration of mechanical ventilation, longer hospital and ICU stays, and increased readmission rates than those without VAP [85, 88]. In TBI patients, each additional day of mechanical ventilation increases pneumonia risk by 7 % [89]. Risk factors for VAP among critically ill stroke patients include chronic lung disease, neurological status at admission, and hemorrhagic transformation [85]. Early tracheostomy has been evaluated as one measure to decrease VAP in severe TBI or stroke [90–92]. Consistent with the literature in the general ICU patient population [93, 94], early tracheostomy in neurocritical care may decrease duration of ventilation and length of stay, but does not appear to decrease VAP rates [90–92].

In summary, while the incidence of VAP is a benchmark for quality in general ICUs, VAP rates are typically greater in the neurocritical care population. Therefore, VAP incidence may not accurately reflect quality of ventilatory care. Research suggests potential contributing factors and adverse outcomes of VAP in neurocritical care; however, additional data are needed to definitively identify specific risk factors and effective interventions for VAP in neurocritical care.

Pressure Ulcers

Pressure ulcers (PU) are a preventable hospital-acquired condition (HAC), and costs associated with their development will no longer be reimbursed in the United States [6]. Pressure ulcers affect up to 33–56 % of all critically ill patients and result in sepsis, additional surgeries, patient depression, and increased hospital costs and LOS [95, 96]. Traditional risk factors for PU include duration of surgery, sedation, fecal incontinence, low protein and albumin, impaired sensation, circulation and mobility, moisture, and increased injury severity [97, 98]. Protocols that include early skin assessment and pressure-reducing mattresses are effective at decreasing hospital-acquired pressure ulcers in the ICU [99].

While there are no studies that evaluate pressure ulcer prevalence or risk factors specifically in a neurocritical care unit, there is research on pressure ulcers among stroke, TBI, and spinal cord injury patients throughout the continuum of care. For example, Wilczweski et al. [100]

investigated pressure ulcer rates among acute spinal cord injury patients in the ICU and reported a 9.6 % PU rate, with hypotension, incontinence, acidosis, steroids, and type of equipment/support surfaces being associated with PU development. However, not all patients had concurrent acute TBI. PU rates for TBI are estimated at 7 % and are associated with increased mortality and poor neurological outcome at 3 months; however estimates are not specific to the critical care setting [101, 102]. Among hospitalized stroke patients, PU rates range from 17 to 28 % in Indonesian and Danish registries [103, 104], to only 2.19 % in the Nationwide Inpatient Sample (NIS) database in the United States [105]. The presence of validated processes of care measures (admission to stroke unit, early antiplatelet or anticoagulant therapy, CT/MRI, physical therapy, nutrition consult, and early mobilization) are associated with decreased PU prevalence [106]. In the NIS sample, which was composed of data from 903, 647 stroke hospitalizations, increased comorbidity scores were associated with PU development, which resulted in increased LOS, costs, and mortality [105]. While the reported PU rates and contributing factors in these studies are not specific to critically ill stroke patients, study samples do include some ICU data in their estimates.

Overall the data suggest PU prevalence and risk factors are similar among the general ICU population and TBI and stroke patients. However, there is a paucity of data specific to neurocritical care. PU estimates in previous studies include both ICU and non-ICU data. Research is needed to accurately report PU rates in neurocritical patients, and to determine the role of additional risk factors inherent in this population, such as severity of illness, sedation, and immobility.

Blood Stream and Cerebrospinal Fluid Infections

Hospital-acquired blood stream infections (BSIs) are classified as catheter-associated blood stream infections (CA-BSI) or catheter-related BSIs (CR-BSI). Rates vary for each depending on causative factors [107]. Guidelines for diagnosis and management of all catheter BSIs have been published by the Infectious Diseases Society of America [108]. Protocols are effective in reducing infections associated with central lines. Specifically, chlorhexidine/silver sulfadiazine or antibiotic-impregnated central venous catheters (CVCs) reduce the risk of colonization [109, 110], and adherence to CVC placement protocols and interdisciplinary team rounds are effective in reducing CR-BSIs [111–113]. CA-BSIs result in increased hospital costs, length of stay, and mortality [114–116]. The majority of research on BSIs includes mixed ICU populations and large databases, which include patients with neurological diagnoses. Research is needed to establish prevalence of catheter-associated BSIs in the neurocritical care population and to determine if causative factors are similar to those in the general ICU patient population.

Within neurocritical care, there is focus on ventriculostomy-related infections (VRIs), which occur in 5–23 % of patients [117]. Risk factors for infection include: concurrent systemic infections, longer duration of monitoring, intraventricular or subarachnoid hemorrhage, an open skull fracture, flushing of the catheter, CSF leakage at the insertion site, and frequent CSF sampling. Two recent systematic reviews and meta-analyses support the use of prophylactic systemic antibiotics at insertion or antibiotic/antimicrobial-coated external ventricular drains (EVD) in decreasing infection rates. However, both reviews indicate additional data from well designed trials are needed for definitive practice recommendations [117, 118]. A separate retrospective study of 141 patients admitted to a neurological intensive care unit reported decreased VRI rates after addition of antibiotic-coated EVD to routine systemic antibiotics [119]. Similar to VAP, use of standard management protocols particularly with a bundled approach may decrease the infection rate. More research is required to determine whether VRIs may be a better quality measure than BSIs in neurocritical care in part because the exact incidence of VRIs may depend on definitions of colonization or infection.

Glycemic Control

Among ICU patients, hyperglycemia is common; up to 90 % develop blood glucose concentrations >110 mg/dL (6.1 mmol/L), and often associated with in adverse patient outcomes [120, 121]. Intensive insulin therapy (IIT) to target normothermia has been extensively studied. While initial research supported the use of IIT among post-operative critically ill patients [122], more recent studies indicate IIT is instead associated with increased risk of hypoglycemia and mortality [123–125]. Hence current recommendations target a blood glucose (BG) concentration between 144 and 180 mg/dL (8–10 mmol/L). These "moderate" insulin protocols are common in ICUs and appear to avoid hyperglycemia and low glucose variability [126, 127]. Data from hospital-based glycemic control programs indicate glycemic control across 576 US hospitals has improved: the mean range of BG results in ICU patients in 2009 was 121.1–217 mg/dL [128], compared to earlier reports of 46.0 % >180 mg/dL. Hospital hypoglycemia (<70 mg/dL) prevalence was 10.1 % in the ICU. Successful protocols include bedside glucose monitoring, nursing driven protocols, and computerized decision-making algorithms [129–131]. While there are clinical and fiscal benefits to glucose control [132–135], there are barriers to "tight" glucose control in the ICU that include lack of a defined target glucose range, health care provider fear of hypoglycemia, and frequent changes to subcutaneous insulin [132–136].

Recently studies have investigated glycemic control in the neurocritical care population. Research in severe brain injury documents deleterious effects of tight glucose control (80–120 mg/dL) in the context of energy metabolism in the brain, and microdialysis studies demonstrate lower brain glucose with tight glucose control (80–100 mg/dL) [137–140]. When investigating the effects of intensive insulin therapy (IIT) (maintenance of blood sugar 80–110 or 80–120 mg/dL) specifically in neurocritical care, cumulative findings indicate IIT is associated with increased episodes of hypoglycemia [22, 139, 141–145], increased mortality [141, 142], increased LOS [142], and decreased functional outcome [146] in stroke, TBI, and SAH.

Three studies report positive benefits of IIT therapy in neurocritical care patients. One observational study ($N = 100$) demonstrated better target BS control and lower incidence of mild or moderate hypoglycemia [147]. A separate trial of 97 severe TBI patients randomized to intensive (target blood sugar 80–120 mg/dL) or conventional insulin therapy (target blood sugar <220 mg/dL) demonstrated increased incidence of hypoglycemia in the IIT group, but shorter ICU LOS. Infection rates, mortality, and GOS scores were similar between the two groups [145]. Among SAH patients at risk for vasospasm ($N = 78$), patients randomized to IIT therapy (target blood sugar 80–120 mg/dL) experienced lower infection rates compared to patients receiving conventional insulin therapy (target blood sugar 80–220 mg/dL); however, there were no differences in mortality, vasospasm, or neurological outcome [148].

A systematic review and meta-analysis of glycemic control included data from 16 RCTs and 1,248 neurocritical care patients [149] and indicated that intensive insulin therapy (target blood sugar 80–120 mg/dL) resulted in frequent hypoglycemia with an associated increase in mortality, though not statistically significant. Poor glucose control in neurocritical care patients was associated with poor neurological outcomes across the various studies. Recommendations from this meta-analysis include moderate glucose control in neurocritical care patients, with an avoidance of intensive insulin therapy [144, 149, 150]. Similar recommendations to maintain BG values between 100 and 180 mg/dL are proposed by the Society for Critical Care Medicine for patients with AIS, intraparenchymal hemorrhage, and TBI [151]. Taken together the various data indicate that IIT is associated with poor outcomes in neurocritical care, likely due to alterations in cerebral metabolism and decreased cerebral glucose levels. Moderate glucose control may be beneficial, but additional trials are needed to establish the evidence base for definitive recommendations.

Quality Indicators for Neurocritical Care and Future Directions

Recently Qureshi et al. [152] proposed quality indicators for intensive care management of ICH, highlighting the complexity of care, and suggesting separate metrics to gauge quality in neurocritical care. Indicators include 27 specific markers across 18 categories: ED evaluation, early neuromonitoring, ICU monitoring, avoidance of DNR for 24 h, hypertension management, early intubation, treatment of intracranial mass effect and repetitive seizures, reversal of elevated INR, treatment of elevated glucose and hyperpyrexia, DVT prophylaxis, dysphagia screening, nutrition initiation, GI prophylaxis, treatment of elevated BP, tracheostomy, treatment for VAP. Metrics were established based on the literature published between 1986 and 2009. Preliminary validation of 25 subjects indicates 44–100 % compliance with one or more quality indicators. A subsequent investigation [153] concludes metrics correlated well with mortality (ROC 0.730, 95 % confidence interval, 0.591–0.869).

These metrics for ICH are a key starting point for gauging quality measures in neurocritical care. Research is needed to validate indicators and determine feasibility and prognostic value for ICH and other neurocritical care diagnoses. Data are available for specific components of these metrics in other patient populations, such as deep vein thrombosis (DVT) prophylaxis, or CAUTI in stroke and TBI [154–158]. As evidence continues to support care by neurocritical units/teams and implementation of evidence-based protocols, it may prove beneficial to incorporate these neuro-specific indicators for quality, with a focus on evaluating not only mortality and length of stay, but also specific neurologic outcomes, such post-discharge functional status.

Conflict of interest Molly McNett and David Horowitz have declared no conflict of interest.

Appendix: Participants in the International Multidisciplinary Consensus Conference on Multimodality Monitoring

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