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EDITORIAL

An algorithm for patients with intracranial pressure monitoring: filling the gap between evidence and practice

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Raised intracranial pressure (ICP) and reduced cerebral perfusion pressure (CPP) are long-established and important causes of secondary brain injury that are associated with worsened clinical outcomes after traumatic brain injury (TBI) [1]. The monitoring and management of ICP/CPP has become the cornerstone of severe TBI management. The Brain Trauma Foundation (BTF) guidelines are considered the gold standard for the medical management of severe TBI [2], but previous versions were formulated using evidence now considered to be of 'low quality' and therefore unsuitable for guideline development. In the most recent, 2016, iteration of the BTF guidelines [2], a more rigorous approach was employed and low-quality studies excluded; between 1996 and 2016, 70% of recommendations were either discarded or downgraded [3]. While this approach improved the 'evidence basis' of the guidelines, it led to criticism that it limited their clinical relevance, in part because of the omission of (non-evidence-based) treatment algorithms [4].

In this issue of the journal, Hawryluk and colleagues [5] present expert recommendations for the management of adults with severe TBI undergoing ICP monitoring. Using a Delphi-method-based consensus approach including eight iterative surveys and an in-person meeting, 42 clinical experts in TBI developed a three-tied algorithm including 18 interventions fundamental to the management of TBI-related intracranial hypertension. There is no recommendation regarding which patients should receive ICP monitoring; the algorithm is designed only to guide ICP-monitor-based management in TBI patients with monitors already in place. Clinicians are therefore left to choose between the BTF recommendations for ICP monitoring [2], those from the American College of Surgeons Trauma Quality Improvement Program [6] or the more pragmatic recommendations developed by a group of European experts for different TBI scenarios and computed tomography findings [7].

Tiered management of TBI-related intracranial hypertension, moving from lower (safer) to higher (more dangerous) therapies, is well established [8]. Thus, much of the content of the Seattle consensus is not new. However, it is the first recommendation amalgamating individual treatments into a single management algorithm for intracranial hypertension that has been developed with some degree of rigor. As such, it will be welcomed by clinicians caring for patients with severe TBI. Except for noting that tier-3 treatments are associated with the highest risks, the Seattle consensus does not emphasize the increasing risk for, and severity of, treatment-related complications as ICP-reducing therapy is escalated from one tier to the next. Clinicians must always consider these risks and complications as well as the potential benefits of treatment escalation in an individual patient (Fig. 1).

In addition to formalizing what is already known, the Seattle consensus includes novel content. It highlights ten treatments that should not to be used, and this is important. Omitting interventions that are dangerous but not efficacious will likely impact patient outcomes as much as, or perhaps more than, administration of the interventions that are recommended. The consensus also

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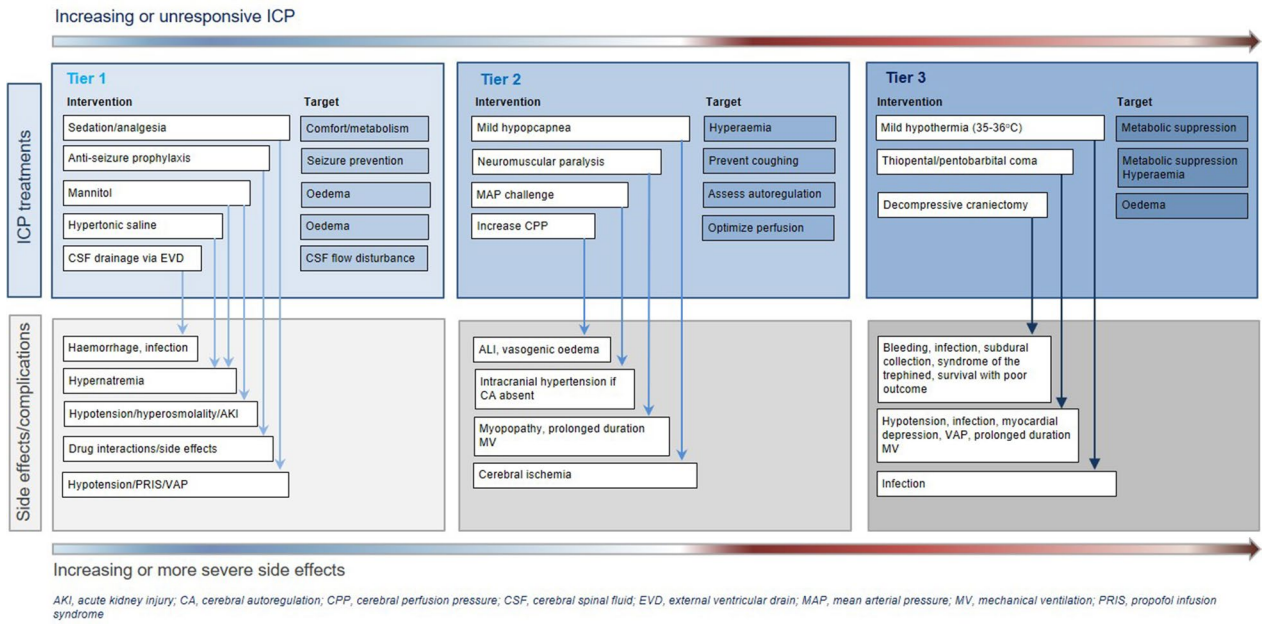

Fig. 1 Tiered treatment of intracranial hypertension in adult traumatic brain injury. Note the increasing risk of treatment-related complications with escalation from one tier to the next. Tier-3 treatments are associated with the most severe complications

highlights the importance of empiric increases in therapy intensity in deteriorating patients with critically elevated ICP. There is clarity on within tier management and what issues should be considered when therapy escalation is required, guidance that is often omitted elsewhere. Specifically, the authors stress that each intervention within a tier is equivalent and that there is no requirement to use all interventions before moving to the next tier. However, the recommendation that a tier, or tiers, of therapy can be skipped if it is 'considered advantageous' is less substantive and offers limited advice for the target audience of clinicians with 'limited experience in monitor-based TBI management.' Other novel elements of the consensus include guidance on two tricky issues—sedation holds to allow clinical neurologic assessment and criteria for ICP-monitor removal. Reflecting their complexity, the authors provide heatmaps to offer ancillary 'consultation' rather than definitive guidance in these areas.

One aspect of the consensus is more controversial. The authors recommend a mean arterial pressure (MAP) challenge to assess the state of autoregulation and, if MAP augmentation results in a reduction in ICP (confirming some degree of intact autoregulation), that consideration be given to increasing systemic blood pressure as a method to reduce ICP. There is a proviso that this intervention should be conducted only by a practitioner capable of interpreting the results because expertise is required to determine whether the reduction in ICP justifies the risks of induced hypertension. This stands in contradiction to the target audience of 'non-experts' and likely reflects the specific interests of the experts involved in the development of the consensus. Importantly, it should be recognized that testing autoregulation by administering a bolus of vasopressor, or longer-term pharmacologically induced increases in MAP, is not without risk. Moreover, this recommendation might be considered somewhat premature. While a recent study from the CENTER-TBI group found that individual ICP thresholds (identified by cerebral autoregulation monitoring) are present in two-thirds of adult TBI patients, and that the mean hourly dose of ICP above a patient's individual ICP threshold is more strongly associated with mortality compared to the dose above the empirical BTF defined threshold of 22 mmHg [9], the majority of studies investigating autoregulation-guided management have been directed toward optimization of CPP rather than ICP [10]. On-going large studies from both the CENTER- and TRACK-TBI consortia investigating autoregulation monitoring in TBI may provide long-awaited new evidence on this important issue.

Strikingly, with the exception of reference to basic autoregulation monitoring, the consensus makes limited mention of the role of other neuromonitoring modalities and how they might impact individualized decisions for ICP control. While such guidance might be considered outside the remit of the Seattle consensus given its target

audience, one area of particular uncertainty is what, if any, action should be taken in response to increases in ICP in the context of normal brain tissue oxygenation or metabolism [11]. Moreover, more detailed guidance on how the overall 'burden' of intracranial hypertension impacts treatment decisions would have been welcome. Using color-coded plots to summarize the relationship between ICP insults (defined by intensity and duration) with 6-month Glasgow Outcome Scale after TBI, Guiza and colleagues [12] found that episodes of higher ICP were tolerated for shorter durations than more modestly elevated ICP. Importantly, impaired cerebrovascular autoregulation or low CPP reduced the ability of the brain to tolerate increases in ICP, highlighting the importance of early intervention to reduce raised ICP particularly if autoregulatory responses are attenuated. These concepts move in the direction of more personalized approaches to ICP management based on current understanding of the underlying pathophysiology of TBI. We consider the 'one size fits all' and escalating 'stair-case' approaches to ICP management undesirable, and strongly support the future development of recommendations for targeted approaches. Further data on this crucially important issue are required.

In summary, the Seattle consensus recommendations go some way to filling the gap between formal, evidence-based guidelines and the everyday needs of clinical practice. Non-experts as well as experts in TBI management will welcome the clarity that these recommendations bring to the ICP-guided management of adult TBI.

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Compliance with ethical standards

Conflicts of interest
MS is Editor-in-Chief of the Journal of Neurosurgical Anesthesiology. AIRM had a consulting agreement with Integra LifeSciences in the past year and is medical monitor of the BOOST-3 trial in the USA. The authors have no other conflicts of interest.

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