Greetings fellow members of the AANS/CNS Section on Neurotrauma & Critical Care. I hope 2017 is going well for you. In my last message to you, I noted the interesting times that have come to pass for neurosurgeons caring for trauma victims. That was not hyperbole but is closer to an understatement. We are healers to be sure, but we traffic in knowledge. We utilize this in an effort to continuously improve the care we deliver to our patients. Knowledge comes to us in many ways, but generalizable knowledge comes from science. Not all science is created equal. Meta science looks at the quality of methods in order to discern high-quality studies and hence more reliable conclusions. Our guidelines for the treatment of various neurotrauma conditions provide this framework. But, the treatment of patients does not begin or end with a framework. The practicing neurosurgeon must apply what he or she knows for the patient’s benefit. I do not think the neurosurgeons’ outcomes or commitment should be judged by what we think we know.

The latest addition of the Brain Trauma Foundation Guidelines for the Management of Severe Traumatic Brain Injury 4th Edition were e-published in September 2016, and the print synopsis was published in the Journal of Neurosurgery (JNS) in January 2017 (1). The new guidelines are different from the old guidelines in many ways. New levels of evidence are labeled from highest quality to lowest: level I, IIA, IIB and III and included the following updated treatment recommendations:

- Bifrontal decompressive craniectomy is not recommended to improve outcomes; however, a large frontotemporal decompressive craniectomy is recommended over a small such craniectomy to reduce mortality and improve neurologic outcomes in patients with severe traumatic brain injury (TBI) (IIA).
- Early short-term hypothermia is not recommended to improve outcomes (IIB).
- An EVD zeroed at midbrain with continuous drainage may be considered to lower intracranial pressure (ICP) more effectively than intermittent use and the use of such drainage in patients with initial GCS less than six in the first 12 hours after injury may be considered (III).
- Nutritional replacement by the fifth day and at latest by the seventh day is recommended to decrease mortality level (IIA).
- Trans-gastric jejunal feeding is recommended to reduce the incidents of ventilator-associated pneumonia (IIB).
- Infection prophylaxis use of PI oral care is not recommended to reduce ventilator associated pneumonia level (IIA).
- Antimicrobial impregnated catheters may be considered to prevent catheter related infections for EVDs (III).
- At the present time, there is insufficient evidence to recommend levetiracetam over phenytoin for preventing early post-traumatic seizures level (IIA).
- Management of severe TBI patients using information from ICP monitoring is recommended to reduce in hospital two-week post injury mortality level (IIB).

continued on page 2
Management of TBI patients based on CPP is recommended level (IIB).

Thresholds for blood pressure maintenance are as follows: BP greater than or equal to 100 mm of mercury for patients ages 50 to 69 years old and greater than or equal to 110 mm of mercury or above for patients ages 15 to 49 or greater than 70 years old may be considered to decrease mortality improved outcomes (III).

Treating ICP greater than 22 mm of mercury is recommended because levels above this level are associated with increased mortality (IIB).

The recommended target for CPP values for favorable outcome is between 60 and 70 mm of mercury (IIB).

The only level I recommendation in the updated version of the guidelines remains the nonuse of steroids for TBI patients. Because of the lack of quality evidence, many of these recommendations are weak, either IIB or III. Therefore, much of the knowledge we use to treat our patients is still what we think we know rather than what we know.

Using high-quality evidence undoubtedly will improve patient care. The American College of Surgeons (ACS), in an effort to improve the overall care of trauma patients, has established the criteria for level I, II and III trauma centers and outlined these criteria in the book Resources for Optimal Care of the Injured Patient (2). Chapter 8 is entirely devoted to criteria for trauma centers regarding neurosurgery and contains the following criteria:

Surgeons taking trauma calls should be aware of and compliant with clinical care parameters established in various neurosurgery guidelines.

Neurosurgeons should provide advice and input to the trauma program.

A neurosurgeon should respond within 30 minutes in accordance with institutional-specific criteria.

A backup plan should be in place for all levels of trauma systems for neurotrauma care if that institution is overwhelmed.

In the case of level III or rural trauma facilities, a trauma surgeon should be periodically credentialed to be able to evaluate and stabilize neurotrauma patients until transfer. Emergency coverage of level I and II centers per neurosurgery should be “immediately” available.

All neurosurgeons providing neurotrauma coverage must be board certified or else have completed an alternative pathway of certification for neurotrauma.

Those neurosurgeons providing neurotrauma care must have general neurosurgery privileges.

Commitment to trauma excellence may be demonstrated in various ways. Neurosurgeons must participate in trauma care review. CME for the neurotrauma director requires 16 hours per year of external trauma related credits. All others participating in neurotrauma call must have 16 hours of trauma credit per year averaged over three years obtained either internally or externally. The neurosurgeons should also participate in performance improvement and patient safety activities at their institution (PIPS).

These criteria set forth by the ACS have been used to develop various institutional criteria to determine neurosurgical participation and quality of care. Such criteria, in my opinion, should be based on the highest quality of evidence with reference to the Brain Trauma Foundation Guidelines level I and IIA recommendations. Otherwise, we risk judging the neurotrauma providers by what which we think we know. The criteria in the ACS resources is reasonable, but attempting to judge neurotrauma quality and commitment by applying criteria based on low-quality evidence is not. For example, as the Brain Trauma Foundation Guidelines struggle to define the appropriate role of ICP monitoring in severe traumatic brain injured patients, it is not appropriate to use the number of ICP monitors placed as a quality indicator, in my opinion. Rather clear outcomes of TBI patient such as mortality, stratified by severity, would seem to be a better quality indicator.

There is little disputing that preventing neurotrauma is the best treatment, so trauma center sponsorship of a ThinkFirst chapter would also be another good quality measure of neurotrauma care at an institution, in my opinion. The topic of concussion also presents us with a conundrum of applying that which we know versus that which we think we know. Many basic questions about this all too common form of neurotrauma have yet to be answered in a rigorous scientific fashion. Such basic questions as whether or not the patient should rest or be involved in structured physical activity following a concussion have yet to be addressed.

An article came to my attention recently, which attempts to provide some information regarding this question. Grool and colleagues attempted to answer the question: Is participation in physical activity within seven days following acute concussion associated with lower rates of persistent post-concussive symptoms in children and adolescents compared with rest (3)? This is a prospective multicenter cohort study of 3,063 children and adolescents ages 5 to 17.99 years. The outcome was the proportion of post-concussion symptoms at 28 days. In the group with participation in early physical activity this was 28.7 percent, while in the conservative resting group this was 40.1 percent. This would seem to indicate that physical activity is beneficial in the recovery of concussion patients and leads to fewer post-concussive symptoms.

However, as the authors point out in their article, there were serious limitations to the study. The most important limitation is that the level of physical activity was self-reported by the patients’ family.
in telephone interviews. I believe this introduces a serious concern for bias. The study does suggest that the question of whether or not we should recommend physical activity to our concussion patients should be studied. There is hope for better scientific studies. In this era of Fitbits and the ubiquity of electronic communication, certainly a trial with more objective measurement of patient activity could be designed.

Finally, an exciting article came to my attention late in 2016 regarding the autonomic nervous system. We all remember that the basic division of the autonomic nervous system is the sympathetic system, which is thoracolumbar in its distribution, and the parasympathetic system, which has a cranial and a sacral outflow. Neuroanatomists, however, have long noted that the sacral parasympathetic system differs in its complexity and distribution from the cranial outflow, suggesting that the pelvic nerves are more similar to the sacral preganglionic sympathetic nerve fibers. In an exciting scientific study using mice, Espinosa-Medina and colleagues from Paris have published an excellent series of experiments in Science, which supply fairly conclusive evidence that indeed the sacral autonomic outflow is sympathetic (4). They did this using genomic markers for known sympathetic neurons during development in wild type, knock in and knock out mice.

In this very elegant set of experiments, they provide very high quality evidence that our long cherished knowledge of the autonomic nervous system dating back to its original description in the late 19th and early 20th century will have to be significantly altered. (See Figure). In the accompanying editorial, it is noted that this new classification has important implications for neuroanatomists and practitioners since entirely different classes of drugs may need to be applied for various disorders of the lower sympathetic (formally parasympathetic) sacral disturbances such as bladder and genitalia disorders (5). This will have important implications for victims of spinal cord injury. Even this revolutionary article, however, does not provide us with absolute knowledge. The study was conducted in mice and will need to be verified in human embryos and subjects before we can move forward with ideas of altered treatment based on these results.

So we continue to do the best we can with knowledge, which is by its very nature imperfect. But do not, my friends, lament the lack of absolute knowledge. The great 20th century mathematician, physicist and philosopher, Jacob Bronowski, uttered these words while standing in a stream running from the abandoned death camp at Auschwitz:

“When people believe they have absolute knowledge, with no test in reality, this is how they behave. This is what men do when they aspire to the knowledge of gods. Science is a very human form of knowledge. We are always at the brink of the known; we always feel forward for what is to be hoped. Every judgment in science stands on the edge of error and is personal. Science is a tribute to what we can know, although we are all fallible (6).”

Thanks for reading, and thanks for being a Section member,

Daniel Bernard Michael, MD, PhD, FAANS
Chair, AANS/CNS Section on Neurotrauma and Critical Care
Southfield, Mich.

References
Dr. Bailes went to Louisiana State University (LSU) medical school and completed his neurosurgery residency at the McGaw Medical Center of Northwestern University, followed by a fellowship at the Barrow Neurological Institute (BNI). Dr. Bailes is a well-known voice in the matter of sport-related brain injuries and research into factors and interventions that can prevent or minimize brain damage during sports. He is also well known for his involvement in the controversy around chronic traumatic encephalopathy (CTE) when it was first brought to light by pathologist Dr. Bennet Omalu. The movie “Concussion” highlights the long-term consequences of football on the brains of those who play it. In the film, Alec Baldwin plays Dr. Bailes, who currently works at the NorthShore Medical Group in Evanston, Ill. Dr. Bailes kindly answered following questions for us:

A: What do you think is the biggest unanswered question in traumatic brain injury (TBI)?
B: What is the cellular injury pathway? Are there common pathways, and can we envision a pharmacological solution for severe TBI?

A: What are recent changes in clinical TBI research?
B: While overall the incidence of severe TBI may be lower, the occurrence of mild TBI has risen, in terms of recognition, importance and the implications for athletes, military service members and all who sustain concussions. In recent years, the majority of clinical research has been focused upon the issues involving mild TBI, both short and long term.

A: What TBI question did you set out to answer?
B: What can be altered in the physics of sports concussion that could lead to less injury and increased protection, specifically by decreasing brain “slosh” by increasing intracranial volume with mild jugular vein compression?

A: What advice could you give to other neurosurgeons dealing with TBI patients?
B: To look for new and innovative methods in diagnosis, management and prevention of TBI, so that neurosurgery stays on the forefront of the management of brain injury.

A: What is your biggest challenge during your day-to-day work?
B: Time management and maximizing productivity, including patient care, research and teaching. This is always both a challenge and the main key to success.

Officer in the Spotlight: Julian E. Bailes Jr., MD, FAANS

Non-invasive Assessment of Intracranial Pressure

Introduction
There is still no ideal method for evaluating intracranial pressure (ICP). While the benefits of continuous, real-time assessment provided by invasive ICP monitoring have long been described, it also comes with distinct limitations (1-10). The appeal of non-invasive ICP monitoring techniques lies in the promise of obviating the need for invasive procedures and avoidance of associated risks. Current non-invasive techniques, however, are limited by inadequate diagnostic accuracy and provide only qualitative estimates of ICP, lacking the necessary quantitative value (11,12).

A variety of non-invasive techniques have been described for assessing ICP; their widespread use, however, remains quite limited. The shortcomings of these non-invasive techniques include the wide range of reference values described for detecting raised ICP, inter-rater variability and qualitative rather than quantitative measurement of ICP (11,13-14). For a non-invasive technique to be considered reliable, it would have to correlate well with invasively measured ICP, predict ICP within 2 mmHg in the 0–20 mmHg range, with a maximum error of 10 percent for ICP > 20 mmHg, which are the specifications supported by the Brain Trauma Foundation (12).

Non-invasive ICP monitoring
The ideal non-invasive technique should be relatively inexpensive, repeatable, portable, radiation-free and allow continuous monitoring. It could facilitate screening and triage in the acute care setting, allow easier long-term monitoring in a neurocritical care environment and augment follow-up assessment in patients with chronic conditions presenting with raised ICP, e.g., hydrocephalus. The benefits of such a technique are certainly not limited to a neurosurgical environment, but include medical emergencies, ophthalmology and aeronautical health assessment continued on page 5
Current methods of non-invasive ICP assessment usually involve evaluating physiological or anatomical characteristics influenced by fluctuations in ICP. The compendium of techniques include both clinical and technological assessment, providing qualitative and quantitative assessments of ICP, with varying accuracy (11,12). These include:

i. Clinical assessment
ii. Methods utilizing natural bony windows in the skull
iii. Methods assessing cerebral fluid dynamics properties
iv. Electrophysiological methods
v. Imaging methods
vi. Novel methods

i. Clinical Assessment

Clinical neurological assessment remains an important initial diagnostic and monitoring tool. Despite notable advances in non-invasive monitoring in the modern era, ongoing clinical assessment remains a fundamental pillar in this respect.

Careful history taking can be an invaluable tool in making the diagnosis of raised ICP. The nuances of clinical evaluation differ in the pediatric and adult population. In children with an open anterior fontanelle (AF), where the skull sutures have not yet fused, an abnormal increase in the head circumference and bulging of the fontanelle are good indicators of raised ICP (14,15). After the cranial sutures have fused, assessment of ICP becomes more difficult. Cranial nerve and gaze palsies can be ominous signs of raised ICP. Bradycardia and hypertension with abnormal respiration (Cushing’s response) may accompany cerebral herniation syndromes and are late features, usually signalling critically raised ICP, requiring emergency treatment. The benefit of a thorough history and clinical examination can therefore not be overemphasized.

ii. Methods Utilising the Natural Bony Windows of the Skull

The most accessible anatomical windows in the bony skull for assessing ICP are transorbital, the auditory canal and the AF in infants.

Transorbital Methods

a. Pupillometry

Infrared pupillometry has been used to quantitatively measure subtle changes in pupil size in response to light stimulus. In normal individuals the pupil decreases by 34-36 percent in size, in response to a standard light stimulus. This response is reduced to 20 percent in head-injured patients, with a reduction of less than 10 percent associated with an ICP > 20 mmHg (16,17). While promising, the clinical applicability of this technique requires further investigation.

b. Intraocular Pressure (IOP)

The indirect transmission of ICP to the orbit via intervening venous anatomy has long been recognized (18). The use of handheld tonometers by clinicians without any specialised training has increased the interest in IOP as a rapid screening tool for raised ICP (19-21). While there appears to be a relationship between an increase in IOP and raised ICP, it does not appear sufficiently accurate for predicting individual patient ICP measurement (22).

c. Optical Coherence Tomography (OCT)

OCT is a technique using broad-band near-infrared light. This application has been found useful in adults and children with raised ICP and papilledema (23-25). SLT uses a laser to produce a 3-D scan of the retinal surface. It can be used as an alternative to OCT when measuring the RFNL.

d. Venous Ophthalmodynamometry (vODM)

This technique usually involves applying a suction cup to the globe in order to increase the IOP until the central retinal vein (CRV) collapses, and begins to pulsate, which usually happens at the point when the applied external pressure nears the VOP, which is an approximate of ICP. The application of external ocular pressure could also trigger the oculo-cardiac reflex, leading to hypotension, which is undesirable, especially if ICP is increased (26).

e. Optic Nerve Sheath Diameter (ONSD)

Changes in the ONSD can be visualized on ultrasound, MRI and CT scan (27-31). Several studies have demonstrated a strong association between distension of the ONSD and an increase in ICP (32-35). The suggested cut-off value in adult studies ranges between 4.1 - 5.9 mm and the definition of increased ICP varies between 14.7 and 30 mmHg (12,32,35). In children there are age-related differences in ONSD cut-off values (36,28). Recent work suggests that using patenty of the anterior fontanelle is a more useful marker for describing ONSD cut-off values (72). Comparison to invasive ICP measurements have allowed the relationship between ONSD and ICP to be evaluated at different ICP thresholds (37). The main limitations of ultrasound-based ONSD measurements are hyperechoic artefacts, inter-rater variability, submillimetric measurements, variation in optic nerve sheath cut-off values and heterogeneity of the patient population (32,36-28,49,38-48).

continued on page 6
Non-invasive Assessment continued from page 5

Methods Utilising the Auditory Canal

The cochlea of the ear is in direct communication with the intracranial subarachnoid space via the cochlear aqueduct. Methods investigating displacement of the tympanic membrane and measurement of sound generated by movement of the ossicles have been described as markers of ICP.

a. Tympanic Membrane Displacement (TMD)
Contraction of the stapedius and tensor tympani muscles is accompanied by a small, measurable displacement of the tympanic membrane from its resting position. As the perilymph and CSF communicate through the cochlear aqueduct, an increase in ICP is directly transmitted to the footplate of the stapes leading to a change in the direction and magnitude of TMD.

Movement of the tympanic membrane altered by increased ICP, where inward displacement is suggestive of high ICP, and outward displacement is suggestive of normal or low ICP (85). While it appears to have a utility in detecting raised ICP, limited accuracy confines it to providing qualitative ICP data (49-51).

b. Otoacoustic Emissions (OAEs)
OAEs are sounds originating from movement of the sensory hair cells within the cochlea in response to auditory stimulation. OAEs that depend on middle-ear function are theoretically influenced by changes in ICP (51). This method has been used as an alternative to TMD, specifically a technique called distortion product otoacoustic emissions (DPOAEs) has been shown to change with ICP (51,53).

Assessment of the Anterior Fontanelle (AF)

Palpation of the AF, measurement of head circumference and shape and palpation of suture ridges during clinical examination are basic, but extremely valuable assessments which can be performed by health care workers at all levels.

ICP assessment via the AF include measuring pulsation of the AF (54,55), use of an aplanation transducer, modified Shiotz tonometer (30) and the Rotterdam Teletransducer (RTT) (56). None of these have been widely used in routine practice and are largely of historic significance. Recently transfontanelle ICP monitoring using an existing ICP probe secured against the AF was described as an accurate technique for detecting raised ICP in infants (57). Where the AF is closed or not reliably patent, other non-invasive techniques may be required to assess ICP.

iii. Methods Assessing Cerebral Fluid Dynamic Properties

Studying dynamic changes in ICP, cerebral blood flow (CBF) and cerebral compliance can be quite challenging. Ultrasound, MRI and infrared spectroscopy have been used to examine some of these dynamic alterations.

Transcranial Doppler Sonography (TCD)

TCD as a technique for evaluating cerebral haemodynamics was described by Aaslid in 1982 (58). It has since been used to measure the cerebral blood flow (CBF) velocity in the circle of Willis and the vertebrobasilar system, both diagnostically and to adjust treatment strategies in a variety of neurovascular disorders (59,60). The most commonly assessed parameters using this arterial waveform are the peak systolic and diastolic velocity, mean velocity, resistance index (RI) and pulsatility index (PI).

The measurement is taken over regions of the skull with the thinnest bony windows (temporal region, transorbital or at the back of the head). TCD is most suited to providing a qualitative estimate (low, normal or high) of ICP (61,59).

TCD remains an attractive alternative to invasive ICP because of its ability to detect cerebral ischemia, its relative cost effectiveness and widespread availability. The main disadvantages are the requirement of a trained and skilled operator to perform and interpret the measurements and the limited accuracy for estimating absolute ICP (62).

Magnetic Resonance Imaging (MRI)-based Elastance Index

MRI-based cine phase-contrast pulse sequences are used to determine the blood and CSF volumetric flow rates within the brain (63,64). Prediction of ICP using this dynamic MRI technique has demonstrated strong correlation with invasive ICP measurement. In children with hydrocephalus, dynamic MRI correlated well with shunt valve opening pressure and symptom resolution (65,66). This promising technique still requires investigation in a larger cohort of patients, is quite expensive and currently impractical for continuous monitoring.

Near Infrared Spectroscopy (NIRS)

NIRS works in the infra-red spectrum (700-1000 nm) of light, where low absorption allows it to easily pass through skin and bone resulting in deep-tissue penetration. Variations in the absorption of infrared light by different substances allow the detection of changes in deoxyhaemoglobin and oxyhaemoglobin concentration. At present NIRS does not provide an estimation of absolute ICP, nor does it facilitate the detection of changes in ICP11. The technique is also limited by the requirement for specialised equipment and the extended period required to obtain the required indices (67).

iv. Electrophysiological Techniques

Electroencephalography (EEG)

The use of a novel technique called EEG power spectrum analysis has recently been reported (68). Power spectral analysis allows a graphical representation of the EEG readings over time. An index called the intracranial pressure index (IPI) was derived using the
EEG power spectrum analysis and this was then correlated with ICP measurements. Recent development of both wireless, portable and field deployable EEG systems have improved the application of this technique (68).

Visual Evoked Potentials (VEP)

Methods using flashing light to stimulate the eye and estimating ICP through recordings obtained from a few occipital EEG electrodes, using the latency of the N2 and P3 waves have been reported using high-density electrode arrays and independent component analysis extraction. Correlation has been demonstrated between the N2 latency of the VEP and ICP in children with hydrocephalus and young adults with head trauma (69-73).

v. Imaging Methods

Imaging remains a fundamental tool in making the diagnosis of raised ICP. Skull x-rays were used to assess whether chronically raised ICP was present by detecting separation of the skull sutures, ‘copper beaten’ appearance of the skull and erosion of the clinoid (74,73,75). This modality is perhaps less useful in the modern era. Imaging features on CT and MRI consistent with clinical findings of raised ICP have been well described (74,77-81).

CT Scan

The CT scan remains the most widely used diagnostic imaging modality for diagnosing raised ICP. A variety of findings on CT have been associated with raised ICP, depending on the underlying etiology. These findings include:

- Absence/compression of the basal cisterns and/or ventricles;
- Midline shift;
- Enlarged ventricles (hydrocephalus);
- Transependymal fluid shift;
- Presence of haematoma/space occupying lesion;
- Blood in the subarachnoid space;
- Size of sulci; and
- Gray/white differentiation.

The benefit of the initial CT scan has been investigated widely in the context of traumatic brain injury (74,78,81-82). CT scans still form the cornerstone of acute imaging in hydrocephalus and TBI (83).

The discussion regarding which of these CT findings correlate best with raised ICP is ongoing (12,11,81-82). While CT scans remain a valuable diagnostic adjunct in the acute diagnosis of raised ICP, it must be remembered that a ‘normal’ CT scan does not rule out raised ICP. In children, additional radiation exposure to the susceptible, developing brain and its compound effect over the lifetime of the child should always be considered (83-87).

MRI Scan

MRI provides superb quality images of the brain, but can be time consuming and costly as a first line diagnostic modality in the acute care setting. MRI techniques for evaluating ICP are based on the relationship between intracranial compliance and pressure (109,141). Specific MRI sequences appear promising, both for screening in acutely raised ICP and for assessment of ICP in other conditions, like hydrocephalus, and has also been used to evaluate the optic nerve sheath diameter as a marker for raised ICP (144). The current role of the MRI as a diagnostic and monitoring tool in neurosurgery, particularly using advanced sequencing techniques, far outweighs its function as a purely non-invasive technique for assessing ICP.

vi) Novel Methods

Ultrasonic time of flight (TOF) for non-invasive assessment of ICP using the propagation speed and attenuation of ultrasound and the respective change within the intracranial components, may provide an estimation of ICP (145-146). Two-depth transorbital Doppler (TDTD) is an innovative technique using the principle of externally applied pressure to the eyeball as a means of equilibrating the blood flow pulsation parameters between the intracranial and extracranial segments of the ophthalmic artery. This technique is based on the assertion that the external applied pressure is equal to ICP at this balance point (147-149). A method using dynamic imaging of the ONS to evaluate the stiffness of the sheath in cases of raised and normal ICP, described a novel parameter, the deformability index (DI) to define the motion of the ONS as a marker of its stiffness, combining the DI with ONSD may improve our understanding of the ONS response in raised ICP to further refine the diagnostic accuracy of this method (52).

Discussion

Despite a relatively long history of innovative thinking regarding suitable techniques for non-invasively assessing ICP, most developments remains in an exploratory phase. The main limitations are inadequate diagnostic accuracy for detecting raised ICP, poor quantitative estimation of ICP and lack of continuous monitoring capability. Most methods appear suitable to identify subjects with low to normal ICP or very high ICP, but are poor at detecting moderately raised ICP, which, arguably, is the most important group. The idea of combining selected non-invasive techniques to improve accuracy, in a ‘non-invasive multi-modality model’ is certainly appealing in principle.

Non-invasive ICP assessment is still most suitable as a screening tool for patients with suspected raised ICP. Future development of non-invasive techniques will likely depend on substantial improvements in their accuracy, ease of use and potential for continuous monitoring.

Llewellyn C. Padayachy, MD, PhD
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8:30-10 a.m.
AANS/CNS 1: THE POST-TRAUMATIC SPINE
AND THE UNSTABLE DECISION
Chair: Ann M. Parr, MD, PhD, FAANS

10:30 a.m.–12 p.m.
AANS/CNS 2: TREATMENT OF THE INJURED BRAIN
Chair: Daniel Bernard Michael, MD, PhD, FAANS
For the last several years, a multi-disciplinary team of traumatic brain injury (TBI) and methodological experts have been hard at work updating the Brain Trauma Foundation’s (BTF’s) flagship guidelines document – the *Guidelines for the Management of Severe Traumatic Brain Injury*. The first edition, published in 1996, broke ground as the first guidelines published by any surgical specialty. The three editions published to date have been credited with improving patient outcomes as well as reducing the costs of TBI care. The guidelines have been among the most respected and adopted guidelines in all of medicine. With nearly 10 years having passed since the publication of the third edition in 2007, an update was needed.

Over the last 10 years, there have been many new and relevant papers published and advances in guidelines methodology and evidence standards. Particularly important has been the influential 2011 publication from the Institute of Medicine: *Clinical Practice Guidelines We Can Trust*. The BTF has aimed to incorporate current best practices. The fourth edition guidelines are also the first to be scrutinized by the AANS/CNS Joint Guidelines Committee. This body and its relevant approval processes developed subsequent to the publication of the third edition. Ultimately, this body and the AANS/CNS granted the fourth edition guidelines a full endorsement, a level of endorsement not commonly bestowed by these groups.

The spirit of advancing guidelines methodology pervaded the fourth edition effort, as was the case in past editions. An important change made in the adjudication of evidence in this edition involved the assessment of applicability. Relevance to North American practice was considered in adjudicating evidence and formulating recommendations. This was influential in adjudicating the BEST:TRIP study and the recommendations related to intracranial pressure (ICP) monitoring. Readers may also be interested in knowing that a full draft of the fourth edition guidelines was initially prepared that excluded class III evidence. The view of the authorship committee was that many class III studies are substantially flawed and that enough class II data now exists for TBI that these flawed studies could be excluded. Ultimately, it was decided that this resulted in too few recommendations and the loss of many entrenched recommendations so the guidelines were completely re-done to include this lower quality evidence in the final version of the document. This latter effort to break new ground was thus aborted. It is also deserves mention that the meta-analysis performed for the prophylactic hypothermia chapter in the third edition guidelines was not repeated in the fourth edition as it was no longer felt appropriate to pool the studies given current standards.

The final version of the fourth edition guidelines incorporates 189 publications as the evidence used to generate 28 recommendations on 18 topics. Of these 28 recommendations, 10 are Level III, 10 are Level IIB and seven are Level IIA. There remains only one Level I recommendation – *that steroids not be administered to TBI victims because of strong evidence of harm*. The recommendations are now arranged into three groups – those related to treatments, monitoring and treatment thresholds.

The chapter on decompressive craniectomy was moved to this guidelines document from its previous home in the Surgical Guidelines, which were published in 2006. Some topics underwent a name change and a minor alteration in scope in comparison to the third edition. This largely reflects that the authorship group felt that the fourth edition guidelines should not delve into general supportive intensive care practices to the extent that the third edition had.

The authorship group faced challenging decisions for some topics where evidence supporting entrenched guidelines no longer meets current evidence standards. This is true for the recommendations on hyperosmolar therapy. It is also true for the recommendations continued on page 10
related to the indications for ICP monitoring which have historically been strongly influenced by Dr. Narayan’s paper published in 1982. For these chapters, the authors ultimately voted to restate the previous recommendations while acknowledging the limits of the evidence.

Nearly all of the treatment thresholds underwent a revision. The changed ICP treatment threshold will likely be the most noteworthy change for most practitioners. Some may recall that this threshold has changed from 25 mmHg to 20–25 mmHg to 20 mmHg in the first, second and third editions, respectively. The new value is 22 mmHg – based on a single paper by Sorrentino et al., which the guidelines authorship group believes provides the best evidence to date. Some have questioned whether the small change is worthwhile. The view of the authors is that we should report the value with as much precision as is possible. Early criticism has also cited emerging evidence that the ICP treatment threshold should be individualized.

The fourth edition guidelines enter an increasingly crowded ‘guideline space’. The American College of Surgeons has provided a Trauma Quality Improvement Program document containing consensus statements. These have been widely viewed as reasonable and practical recommendations; however, they have not undergone an independent peer review nor are they published in a journal. The Neurocritical Care Society has published a number of relevant consensus statements in recent years on the care of patients with severe TBI. A particularly important recommendation they provide is the 20 mmHg threshold for brain oxygen monitoring that is now used in most centers. Despite these competitors, the fourth edition BTF guidelines are unique in the field. This document ultimately provides a very rigorous review of the evidence and declines to provide recommendations in the absence of evidence. This has caused some to question the utility of these recommendations as they do not provide a full picture of how to manage a patient with a severe TBI. The BTF intends for individual institutions to develop their own protocols, which incorporate the fourth edition recommendations while considering local resources and preferences.

The BTF acknowledges that there is great demand for a new treatment algorithm; it was the most requested reprint from the first and second editions of the BTF’s Management Guidelines. Many expressed disappointment that one did not accompany the third edition. The BTF has developed a three-tiered framework for conceptualizing the treatment of ICP elevation and brain hypoxia. While this has not been formally published, it strongly influenced the protocol for patient management in some of the major TBI trials that have recently been completed. A new effort is underway to develop an entirely new algorithm and there are tentative plans for a meeting of panelists in the summer of 2017. Early planning suggests that this algorithm may endeavor to be adaptable to both resource rich and resource poor environments.

Perhaps the most notable characteristic of the fourth edition guidelines is that they are intended to be the last formally published update. The plan is to now transition to a “Living Guidelines” system which involves frequent updates – at least once per year or when an important new publication comes along. It is hoped that this will better meet the demands of the guidelines consumer and that this will, yet again, break new ground for guidelines methodology. Early revisions are planned for the decompressive craniectomy chapter so as to incorporate the RESCUEicp findings. Some new topics are also being discussed. This could be a window into the future of all clinical practice guidelines. It is interesting to consider; however, that while tremendous improvements in care have come from standardizing care, provision guidelines are at odds with the notion of personalized medicine. In the TBI field, highly individualized care is likely to be centered around patients’ unique physiology and physiologic states. I cannot wait to see how the field evolves and what the role of guidelines will be.

By Gregory W.J. Hawryluk, MD, FAANS

### Key Changes to Treatment Thresholds:

<table>
<thead>
<tr>
<th></th>
<th>Previously Recommended Threshold</th>
<th>New Threshold Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICP</td>
<td>&lt; 20 mmHg</td>
<td>&lt;22 mmHg</td>
</tr>
<tr>
<td>CPP</td>
<td>50–70 mmHg</td>
<td>60–70 mmHg</td>
</tr>
<tr>
<td>SBP</td>
<td>&gt; 90 mmHg</td>
<td>&gt;100 for patients 50–69y and &gt;110 for all others</td>
</tr>
<tr>
<td>PbtO₂</td>
<td>15 mmHg</td>
<td>No recommendation</td>
</tr>
<tr>
<td>SjVO₂</td>
<td>&gt;50%</td>
<td>&gt;50%</td>
</tr>
</tbody>
</table>
Key Changes to Topics and Recommendations (adapted from Appendix A of the 4th Edition Guidelines)

<table>
<thead>
<tr>
<th>Topic</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decompressive Craniectomy</td>
<td>New topic for fourth edition.</td>
</tr>
<tr>
<td>Prophylactic Hypothermia</td>
<td>Meta-analysis was not repeated and the current evidence synthesis is now qualitative.</td>
</tr>
<tr>
<td>Hyperosmolar Therapy</td>
<td>This topic focused on the comparative effectiveness of different hyperosmolar agents. Eisenberg, 1988, is no longer included in this topic.</td>
</tr>
<tr>
<td>Cerebrospinal Fluid Drainage</td>
<td>New topic for fourth edition.</td>
</tr>
<tr>
<td>Ventilation Therapies</td>
<td>This title was changed from Hyperventilation.</td>
</tr>
<tr>
<td>Anesthetics, Analgesics and Sedatives</td>
<td>No major change.</td>
</tr>
<tr>
<td>Steroids</td>
<td>No major change.</td>
</tr>
<tr>
<td>Nutrition</td>
<td>New recommendations and addition of new studies.</td>
</tr>
<tr>
<td>Infection Prophylaxis</td>
<td>Scope limited to TBI-related issues (not general infection prevention).</td>
</tr>
<tr>
<td>Infection Prophylaxis</td>
<td>No change in recommendations. Notation added that some evidence is indirect.</td>
</tr>
<tr>
<td>Deep Vein Thrombosis Prophylaxis</td>
<td>Scope limited to TBI-specific risk and treatment issues, though indirect evidence was used.</td>
</tr>
<tr>
<td>Intracranial Cerebral Pressure Monitoring</td>
<td>Clarification of scope and questions for this topic.</td>
</tr>
<tr>
<td></td>
<td>Studies from prior editions that were reclassified for this topic are not included.</td>
</tr>
<tr>
<td>Cerebral Perfusion Pressure Monitoring</td>
<td>CPP Monitoring was made its own section.</td>
</tr>
<tr>
<td>Advance Cerebral Monitoring</td>
<td>Renamed.</td>
</tr>
</tbody>
</table>
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- **002** Current Treatments and Controversies in Traumatic Brain Injury International Symposium
- **008** Update on the Management of Spine and Spinal Cord Injury
- **014** Neurosurgical Care of Athletes - Concussion, Spine, Peripheral Nerve and Return-to-play
- **019** You Are Never Too Old for Surgery: Spine Management in an Aging Population