WSES consensus conference guidelines: monitoring and management of severe adult traumatic brain injury patients with polytrauma in the first 24 hours

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Abstract

The acute phase management of patients with severe traumatic brain injury (TBI) and polytrauma represents a major challenge. Guidelines for the care of these complex patients are lacking, and worldwide variability in clinical practice has been documented in recent studies. Consequently, the World Society of Emergency Surgery (WSES) decided to organize an international consensus conference regarding the monitoring and management of severe adult TBI polytrauma patients during the first 24 hours after injury. A modified Delphi approach was adopted, with an agreement cut-off of 70%. Forty experts in this field (emergency surgeons, neurosurgeons, and intensivists) participated in the online consensus process. Sixteen recommendations were generated, with the aim of promoting rational care in this difficult setting.

Keywords: Traumatic brain injury, Polytrauma, Bleeding, Hemorrhage, Monitoring, Management

Introduction

Traumatic brain injury (TBI), both isolated and in combination with extra-cranial lesions, is a global health problem associated with high mortality and disability [1, 2]. In addition, post-traumatic bleeding is a leading cause of preventable death among injured patients [3–5]. A multicenter observational study, involving 1536 trauma patients, identified exsanguination as the most frequent cause of early death [5]. The same study, however, found TBI as the most common cause of delayed mortality and disability [5]. Therefore, the combination of brain damage and extra-cranial injuries, causing bleeding, shock, and arterial hypotension, is especially challenging. On the one hand, bleeding can be rapidly life-threatening and has to be corrected promptly; in this regard, various strategies, often including “permissive arterial hypotension”, have been proposed [6–10]. On the other hand, arterial hypotension may exacerbate cerebral secondary damage and is associated with further worsening of the outcome [11].

A recent international survey revealed great variability in clinical practice during the acute phase management of polytrauma patients with TBI [12]. Moreover, guidelines regarding optimal monitoring and management strategies in this setting are lacking [10, 13]. Considering
the above, the World Society of Emergency Surgery (WSES) promoted an international consensus conference on monitoring and management of severe adult TBI polytrauma patients during the first 24 hours after injury.

**Methods**
A modified Delphi approach was adopted. Three subsequent online questionnaires were administered between January and May 2019. The agreed cut-off for the consensus was defined as 70% of experts in agreement, in keeping with recent initiatives in this field [14, 15]. Forty experts (emergency surgeons, neurosurgeons, and intensivists) in the management of severe TBI patients with polytrauma [Abbreviated Injury Score (AIS) ≥ 3 at least in 2 body regions] participated in the consensus process (see Appendix 1 in Additional file 1). Consensus statements were developed by 3 authors (EP, NS, and FC) based on a non-systematic literature search and evaluated by the expert panel through an electronic consultation. Sixteen recommendations related to monitoring and management of adult severe TBI patients with polytrauma in the acute phase (first 24 hours) were generated. Once a consensus (> 70% agreement) for each statement was achieved, a summary guideline, together with a corresponding algorithm, was circulated to all participants for the final acceptance. A summary of the data was presented and discussed at the 6th International WSES meeting held in Nijmegen (The Netherlands) from 26 to 28 June 2019. The present paper was drafted after the meeting and distributed to all participants for review and final approval before submission.

**Notes on the use of the current consensus**
The aim of this consensus is to support clinician’s decision-making in the management of bleeding TBI polytrauma patients in the first 24 hours after injury. The included statements are created to assist the physician’s clinical judgment, which is necessary to provide appropriate (personalized) therapy. Advanced neuromonitoring and specific management strategies that can be indicated in a later stage are not addressed. Considering the lack of high-quality studies in this setting, we adopted a modified Delphi approach involving experts from different countries worldwide; this approach is probably less rigorous than evidence-based guidelines [13]. However, we think that our methodology can provide useful recommendations in this challenging clinical scenario.

The practice guidelines promulgated in this work do not represent a standard of practice. They are suggested plans of care, based on best available evidence and the consensus of experts, but they do not exclude other approaches as being within the standard of practice. However, responsibility for the results of treatment rests with those who are directly engaged therein, and not with the consensus group.

**Results**
Agreement was reached on sixteen recommendations (Table 1); they are listed below with the percentage of agreement and associated comments. Figure 1 shows the consensus algorithm.

**Recommendation 1**
All exsanguinating patients (life-threatening hemorrhage) require immediate intervention (surgery and/or interventional radiology) for bleeding control.
Agreement: 100%.

**Recommendation 2**
Patients without life-threatening hemorrhage or follow-up measures to obtain bleeding control (in case of life-threatening hemorrhage) require urgent neurological evaluation [pupils + Glasgow Coma Scale (GCS) motor score (if feasible), and brain computed tomography (CT) scan] to determine the severity of brain damage (life-threatening or not).
Agreement: 100%.

**Recommendation 3**
After control of life-threatening hemorrhage is established, all salvageable patients with life-threatening brain lesions require urgent neurosurgical consultation and intervention.
Agreement: 100%.

**Recommendation 4**
Patients (without or after control of life-threatening hemorrhage) at risk for intracranial hypertension (IH)* (without a life-threatening intracranial mass lesion or after emergency neurosurgery) require intracranial pressure (ICP) monitoring regardless of the need of emergency extra-cranial surgery (EES) [16, 17].
* = patients in coma with radiological signs of IH.
Agreement: 97.5%.

**Recommendation 5**
We recommend maintaining systolic blood pressure (SBP) > 100 mmHg or mean arterial pressure (MAP) > 80 mmHg during interventions for life-threatening hemorrhage or emergency neurosurgery. In cases of difficult intraoperative bleeding control, lower values may be tolerated for the shortest possible time.
Agreement: 82.5%.
We recommend red blood cell (RBC) transfusion for hemoglobin (Hb) level < 7 g/dl during interventions for life-threatening hemorrhage or emergency neurosurgery. Higher threshold for RBC transfusions may be used in patients “at risk” (i.e., the elderly and/or patients with limited cardiovascular reserve due to pre-existing heart disease). Agreement: 97.5 %.
Recommendation 7
We recommend maintaining an arterial partial pressure of oxygen (PaO2) level between 60 and 100 mmHg during interventions for life-threatening hemorrhage or emergency neurosurgery.

Agreement: 95%.
Recommendation 8
We recommend maintaining an arterial partial pressure of carbon dioxide (PaCO2) level between 35 and 40 mmHg during interventions for life-threatening hemorrhage or emergency neurosurgery.
Agreement: 97.5%.

Recommendation 9
In cases of cerebral herniation, awaiting or during emergency neurosurgery, we recommend the use of osmotherapy and/or hypocapnia (temporarily).
Agreement: 90%.

Recommendation 10
In cases requiring intervention for life-threatening systemic hemorrhage, we recommend, at a minimum, the maintenance of a platelet (PLT) count > 50,000/mm³. In cases requiring emergency neurosurgery (including ICP probe insertion), a higher value is advisable.
Agreement: 100%.

Recommendation 11
We recommend maintaining a prothrombin time (PT)/ activated partial thromboplastin time (aPTT) value of < 1.5 normal control during interventions for life-threatening hemorrhage or emergency neurosurgery (including ICP probe insertion).
Agreement: 92.5%.

Recommendation 12
We recommend, if available, that point-of-care (POC) tests [e.g., thromboelastography (TEG) and rotational thromboelastometry ROTEM] be utilized to assess and optimize coagulation function during interventions for life-threatening hemorrhage or emergency neurosurgery (including ICP probe insertion).
Agreement: 90%.

Recommendation 13
During massive transfusion protocol initiation, we recommend the transfusion of RBCs/Plasma/PLTs at a ratio of 1/1/1. Afterwards, this ratio may be modified according to laboratory values.
Agreement: 92.5%.

Recommendation 14
We recommend maintaining a cerebral perfusion pressure (CPP) ≥ 60 mmHg when ICP monitoring becomes available. This value should be adjusted (individualized) based on neuromonitoring data and the cerebral autoregulation status of the individual patient.
Agreement: 95%.

Recommendation 15
In the absence of possibilities to target the underlying pathophysiologic mechanism of IH, we recommend a stepwise approach [18], where the level of therapy, in patients with elevated ICP, is increased step by step, reserving more aggressive interventions, which are generally associated with greater risks/adverse effects, for situations when no response is observed.
Agreement: 97.5%.

Recommendation 16
We recommend the development of protocols, in conjunction with local resources and practices, to encourage the implementation of a simultaneous multisystem surgery (SMS) [including radiologic interventional procedures] in patients requiring both intervention for life-threatening hemorrhage and emergency neurosurgery for life-threatening brain damage.
Agreement: 100%.

Discussion
Critical clinical decisions regarding hemorrhage control in TBI polytrauma patients
Life-threatening hemorrhage is one of the major preventable causes of early death after trauma [3–5]. Therefore, precise and early control of hemorrhage, with associated restoration of circulating blood volume, remains a priority [9, 19, 20]. It is well accepted that hemorrhage can be controlled by damage control surgery and/or interventional radiology [8, 21]. Typically, a basic clinical neurological evaluation (GCS motor score + pupils) with a brain CT scan is necessary both to determine the patient’s salvage-ability and to address the possible need for additional monitoring and urgent neurological intervention [13, 19, 22]. Often, uncontrolled hemorrhage in TBI polytrauma patients may require simultaneous multisystem surgery [23–25]. The main objective should be the control of bleeding and the avoidance/minimization of secondary brain insults. This approach, frequently adopted in the war trauma setting, but rarely in the civilian one, requires established protocols and a strict collaboration between different surgical teams (including interventional radiologists) [23]. Kinoshita et al. performed a retrospective study to evaluate the efficacy of a hybrid emergency room (capable of deploying SMS) on functional outcomes in TBI polytrauma patients [24]. This system was significantly associated with both shorter times to initiate CT scanning/emergency surgery and fewer unfavorable outcomes at 6 months post-injury. The results of a recent survey [12] showed that, although few centers are currently equipped to perform SMS for hemorrhage in TBI polytrauma patients, the majority of the responding centers considered the ability to perform SMS as important, very important, or even mandatory. Although this consensus reinforces the
The presence of hypoxia, historically and pathophysiologically defined as a peripheral oxygen saturation (SpO2) < 90% (corresponding near to a PaO2 of 60 mmHg), has been associated with poor outcomes in TBI patients both in the pre-hospital and in-hospital setting [27, 33, 34]. A retrospective study, enrolling 3420 severe TBI patients, showed that both a PaO2 < 110 mmHg and a PaO2 > 487 mmHg were associated with increased mortality and worsened neurological outcomes [35]. Another retrospective study, involving 1547 severe TBI patients, reported (1) an association between early (within 24 hours from admission) hyperoxia (defined as a PaO2 > 200 mmHg) and mortality/short-term functional outcomes (lower GCS discharge scores), and (2) an association between a PaO2 < 100 mmHg and mortality [36]. The authors suggest that the negative effects of hyperoxia may have been related to hyperoxia-induced oxygen-free radical toxicity. However, a transient hyperoxia, achieved by increasing the oxygen content and delivery, may be potentially beneficial in trauma patients with severe anemia [37]. Hypocapnia, induced by hyperventilation, is also known to be associated with the risk of development of cerebral ischemia [38] and worsened neurological outcome after TBI [39]. Moreover, in cases of hypovolemia, an increase in airway pressure (sometimes associated with hyperventilation) can reduce venous return, thereby inducing or exacerbating arterial hypotension [40].

Platelets are known to play a key role in hemostasis after trauma [41]. A reduction in PLT count is associated with an increase in mortality and the progression of post-traumatic intracranial bleeding [42–44]. Recent guidelines recommend the maintenance of a PLT count > 50,000/mm³ (grade 1 C) in polytrauma patients and further recommend a more stringent cut-off (> 100,000/mm³) in case of ongoing bleeding and/or TBI (grade 2 C) [44]. Furthermore, coagulopathy is frequently observed after trauma and is often associated with increased mortality [41, 45]. In TBI polytrauma patients, coagulopathy is associated with intracranial bleeding progression and unfavorable neurological outcomes [46, 47].

Massive transfusion is frequently utilized in trauma patients [19, 20]. The Pragmatic Randomized Optimal Platelet and Plasma Ratios (PROPPR) study, involving 680 trauma patients with major bleeding, was performed to determine the safety and the effectiveness of a transfusion strategy involving plasma, PLTs, and RBCs in a 1:1:1 ratio compared with a 1:1:2 ratio. This study showed that none of the strategies resulted in significant differences in mortality. However, more patients in the 1:1:1 group achieved hemostasis and fewer experienced death due to exsanguination within the first 24 hours [47]. Given the negative effects of coagulopathy on TBI (42–44, 46–47), we recommend the initiation of a transfusion protocol of RBCs/plasma/PLTs at a ratio of 1:1:1. This ratio may be modified afterwards according to laboratory values.
Point-of-care tests (i.e., TEG, ROTEM, etc.) are increasingly used in the evaluation of coagulation function in trauma patients with hemorrhagic complications [10, 20, 41]. These tests can be utilized to obtain a rapid assessment of hemorrhage and to assist in clinical decision-making; they can further provide critical information about specific coagulation deficiencies [10, 41, 49]. Moreover, they can be particularly useful in patients taking novel oral anticoagulants (NOACs) and in the evaluation of PLT dysfunction induced by trauma and/or drugs [10]. In light of the above, these tests may be useful in TBI polytrauma patients [50].

Conclusions
Future studies are needed and should be encouraged to improve clinical outcomes in this challenging setting. In the absence of more compelling data, the present practical consensus conference was intended to establish and provide a shared, multidisciplinary approach to deliver the best possible care during the very early stages of management of TBI polytrauma patients.

Supplementary information
Supplementary information accompanies this paper at https://doi.org/10.1186/s13017-019-0270-1.

Additional file 1. Appendix 1. List of participants.

Abbreviations
AIS: Abbreviated Injury Score; aPTT: Activated partial thromboplastin time; BTF: Brain Trauma Foundation; CPP: Cerebral perfusion pressure; CT: Computed tomography; EES: Emergency extra-cranial surgery; GCS: Glasgow Coma Scale; Hb: Hemoglobin; ICP: Intracranial pressure; IH: Intracranial hypertension; MAP: Mean arterial pressure; NOACs: Novel oral anticoagulants; PaCO2: Arterial partial pressure of carbon dioxide; PaO2: Arterial partial pressure of oxygen; PLT: Platelet; POC: Point-of-care; PROPPR: Pragmatic Randomized Optimal Platelet and Plasma Ratios; PT: Prothrombin time; RBC: Red blood cell; ROTEM: Rotational thromboelastometry; SBP: Systolic blood pressure; SMS: Simultaneous multisystem surgery; SpO2: Peripheral oxygen saturation; TBI: Traumatic brain injury; TEG: Thromboelastography; TRICC: Transfusion Requirements in Critical Care; WSES: World Society of Emergency Surgery

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None.

Authors’ contributions
EP, SR, NS, and FC have designed the study. EP has performed acquisition of data. EP has done the analysis and interpretation of data. EP, SR, NS, and FC have drafted the article. All authors have revised it critically for important intellectual content. All authors have given final approval of the version to be submitted.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Not applicable.

Consent for publication
Not applicable.

Competing interests
AWK has consulted for the Innovative Trauma Care and Acetyl Corporations. PFS is the co-inventor of the US patent no. 11.441.828 entitled: “Inhibition of the alternative complement pathway for treatment of traumatic brain injury, spinal cord injury, and related conditions.” All other authors declare that they have no competing interests.

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