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REVIEW

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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

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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 following 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%.

Table 1 Summary of consensus conference recommendations

Number	Recommendation	Agreement (%)
1	All exsanguinating patients (life-threatening hemorrhage) require immediate intervention (surgery and/or interventional radiology) for bleeding control.	100
2	Patients without life-threatening hemorrhage or following measures to obtain bleeding control (in case of life-threatening hemorrhage) require urgent neurological evaluation [pupils + Glasgow Coma Scale motor score (if feasible), and brain computed tomography (CT) scan] to determine the severity of brain damage (life-threatening or not).	100
3	After control of life-threatening hemorrhage is established, all salvageable patients with life-threatening brain lesions require urgent neurosurgical consultation and intervention.	100
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].	97.5
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 value may be tolerated for the shortest possible time.	82.5
6	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).	97.5
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.	95
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.	97.5
9	In cases of cerebral herniation, awaiting or during emergency neurosurgery, we recommend the use of osmotherapy and/or hypocapnia (temporarily).	90
10	In cases requiring intervention for life-threatening systemic hemorrhage, we recommend, at a minimum, the maintenance of a platelet (PLT) count > 50.000/mm^3. In cases requiring emergency neurosurgery (including ICP probe insertion), a higher value is advisable.	100
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).	92.5
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).	90
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.	92.5
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.	95
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.	97.5
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.	100

*Patients in coma with radiological signs of intracranial hypertension

Recommendation 6

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 %.

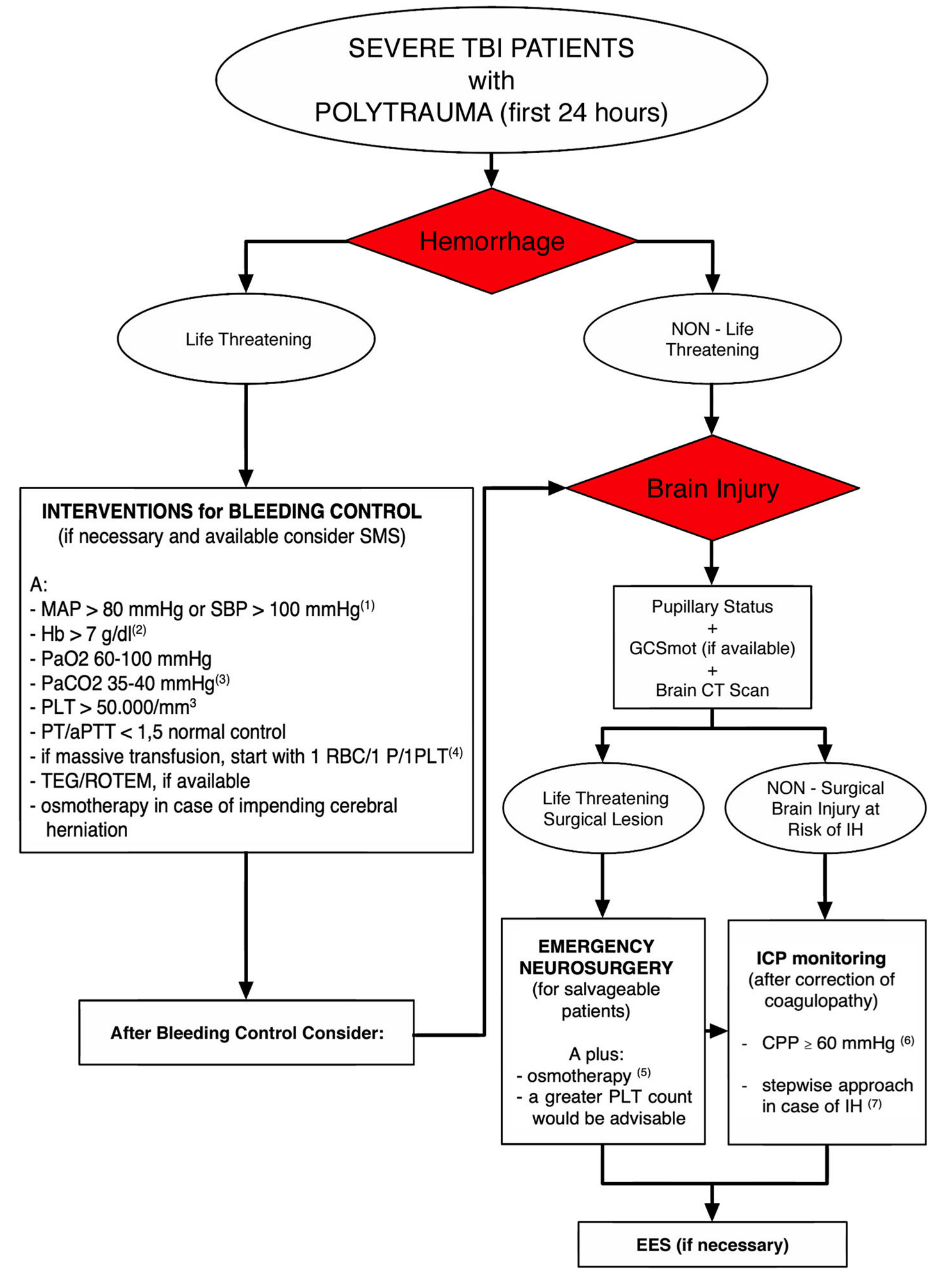

Fig. 1 Consensus algorithm. (1) Lower values could be tolerated, for the shortest possible time, in case of difficult intraoperative bleeding control. (2) Higher threshold could be used in patients "at risk" (i.e., elderly and/or with limited cardiovascular reserve because of pre-existing heart disease). (3) Lower values, temporarily, only in case of impending cerebral herniation. (4) Afterwards, this ratio can be modified according to laboratory values. (5) Not only in case of impending cerebral herniation but also for cerebral edema control. (6) This value should be adjusted (individualized) considering neuromonitoring data and cerebral autoregulation status. (7) This approach is recommended in the absence of possibilities to target the underlying pathophysiologic mechanism of IH. *Abbreviations:* SMS = systemic multisystem surgery (including radiologic interventional procedures), CT = computed tomography, GCS = Glasgow Coma Scale (mot = motor part of GCS), MAP = mean arterial pressure, SBP = systolic blood pressure, Hb = hemoglobin, PaO2 = arterial partial pressure of oxygen, PaCO2 = arterial partial pressure of carbon dioxide, RBC = red blood cell, P = plasma, PLT = platelet, PT = prothrombin time, aPTT = activated partial thromboplastin time, TEG = thromboelastography, ROTEM = rotational thromboelastometry, ICP = intracranial pressure, CPP = cerebral perfusion pressure, IH = intracranial hypertension, EES extracranial emergency surgery

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/mm^3. 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 salvageability and to address the possible need for additional monitoring and urgent neurosurgical 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 implementation of this approach, future studies designed to evaluate the usefulness of SMS in polytrauma TBI patients are warranted.

Preservation/protection of the injured brain during interventions for extra-cranial bleeding control

In TBI polytrauma patients, it is mandatory to minimize secondary or delayed insults, like hypoxia and arterial hypotension, while emergency surgeons control extra-cranial bleeding. Hypotension (defined as a SBP < 90 mmHg) is a well-recognized secondary insult, known to be associated with unfavorable neurological outcome [26, 27]. Moreover, recent observational studies suggest that the currently established threshold of 90 mmHg may, in fact, be too low [28, 29]. Further trials are required to identify the correct SBP value in this setting. While Brain Trauma Foundation (BTF) guidelines suggest that SBP be maintained at ≥ 100 mmHg for patients 50–69 years or at a minimum of ≥ 110 mmHg for patients 15–49 years or older than 70 years [13], we have chosen a value of 100 mmHg as a threshold for bleeding TBI polytrauma patients. Furthermore, we suggest that lower values of SBP be maintained for the shortest possible time, particularly in cases associated with difficult intraoperative bleeding control.

The optimal Hb value in TBI polytrauma patients remains to be determined. The Transfusion Requirements in Critical Care (TRICC) study showed no differences in 30-day mortality between the use of a liberal transfusion strategy (trigger for transfusion Hb > 10 g/dl) and the use of a more restrictive transfusion strategy (trigger for transfusion Hb > 7 g/dl) in 838 critically ill patients [30]. A subgroup analysis of the TRICC trial, focusing on 67 severe TBI patients, confirmed no survival benefit comparing the liberal vs. the restrictive transfusion strategy [31]. Robertson et al. [32] reported the results of a randomized clinical trial designed to compare the effects of erythropoietin and two hemoglobin transfusion thresholds (7 and 10 g/dL) on neurological recovery after TBI. These investigators found that the administration of erythropoietin or the maintenance of Hb value > 10 g/dL was not associated with improved neurological outcome at 6 months. Moreover, the use of a transfusion threshold of 10 g/dL was associated with a higher incidence of adverse events. Given the absence of additional published studies, we recommend a Hb threshold of 7 g/dl in TBI polytrauma patients. Higher thresholds for RBCs transfusions in patients "at risk" (i.e., elderly and/or with limited cardiovascular reserve because of pre-existing heart disease) may be considered [30].

Randomized controlled trials targeting the optimal PaO2 and PaCO2 values in TBI polytrauma patients are lacking. 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/mm^3 (grade 1 C) in polytrauma patients and further recommend a more stringent cut-off (> 100.000/mm^3) in case of ongoing bleeding and/or TBI (grade 2 C) [10]. 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 [48]. 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 hemostasis 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.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

AWK has consulted for the Innovative Trauma Care and Acelity 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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