The Need for a Physiological Classification of Hemorrhagic Shock

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Abstract

Classifications mean to conceptualize in a cluster and rapidly summarize the assessment and management of a clinical scenario. In the specific case of a hemorrhagic shock (HS), a classification should serve the purpose of allowing a rapid clinical assessment of the shock level in its dynamics in the correlation with the decision-making on timing of source control, and possibly on whether to apply damage control surgery (DCS) strategy or not. ATLS® classification of HS is not sensitive and specific enough to help decision-making in reference to the timing of management, based only on the amount of blood loss that may be or may not rightly estimated, for example, blood loss on the floor in penetrating injuries before theatre. Moreover, it focuses also on other parameters, which are taken singularly, instead of the individual generalized physiological response to hemorrhage, which is the core by definition of the derangement we call “shock.” It is unhelpful, difficult, and impractical to apply as well. A new classification, which may well be called as the “physiological HS classification” or “therapeutic HS classification,” was proposed since 2010, following the new developments on microcirculation and an already going-on sensible praxis among some trauma surgeons. It bases on some physiological considerations such as the significance of fluid-blood resistant hypotension, body natural hemostatic mechanisms, the right definition of shock, and the relevance that hemorrhage-triggered ischemia-reperfusion toxemia and systemic inflammatory response have in critical illness scenarios as secondary insults from ischemia, which is what we mean to prevented with DCS. The key factor remains the persistence of hypotension, following fluid challenge.

Keywords: Cardiac reserve, fluid challenge test, hemorrhagic shock, hypotension, microcirculation

Introduction

Classifications mean to summarize rapidly the assessment and management of a clinical scenario, or of an issue. In the specific case of hemorrhagic shock (HS), a classification should serve the purpose of allowing a rapid clinical assessment of the shock level in its dynamics in the correlation with the decision-making on timing of source control, and possibly on whether to apply damage control surgery (DCS) strategy or not.

Past and Current Classifications

ATLS® classification of HS is not sensitive and specific enough to help decision-making in reference to the timing of management, being based only on the amount of blood loss that may or may not be rightly estimated, for example, blood loss on the floor in penetrating injuries before theater; and it is unhelpful, difficult, and impractical to apply too.[1]

Blood loss measurements remain a useless, misleading, and distracting parameter, even more so when we face a “real” a hemorrhage progressing toward exsanguination. The historical and experimental basis behind are also faulty. There is variability between species and among individuals in the same species, variability of distribution of adrenergic receptors between species, individuals and organs, and a different physiology reserve among individuals. Moreover, the relying on findings from experiments on innocent animals pinned to wall and left to exsanguinate slowly until death and with leg-to-trunk ratio different from humans, therefore with compensatory mechanisms incomparable with the ours, makes blood loss calculations an useless misleading and distracting exercise.

There is a second basic error: it focuses on the amount of blood loss and other parameters taken singularly instead of the

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individual systemic response to hemorrhage, which is the core by definition of the derangement, we call “shock.”[3]

The previous “anatomical” classification by Holcroft had advantages overlooked and not re-captured by the ATLS® one, namely the progression of the effects of a hemorrhage on the different organs and systems, a more reliable indicator than the amount of blood itself in guiding timing of intervention. Nevertheless, the anatomical classification, despite being more functional and useful than the ATLS one, does not keep in account the preexistent different organ physiological reserves or tries to foresee the level at which hypotension, crucial parameter signaling decompensation, occurs.[10] [Accessory File – Fig 1].

ATLS classification validity or usefulness has never been confirmed by any study, justifying a correlation of the variable with the categorizations.

Mutschler et al. have correctly commented: <<The suggested classification of hypovolaemic shock by ATLS should be questioned. The combination of heart rate, systolic blood pressure and Glasgow Coma Scale displays substantial deficits in reflecting clinical reality.>>.[4] Tachycardia, likewise tachypnea, can be due to other factors than blood loss like associated hypoxemia from lung/airway problems or to pain. Another pitfall in using tachycardia is the occasional co-presence of possible drugs interfering with heart rate, running into the patient (cocaine, B-Blockers).

For these reasons, the shock index (S/I) is not of great utility in the assessment of the degree of hemorrhage and in the decision-making for timing the intervention of source control. GCS well correlates to the level of consciousness in isolated traumatic brain injury (TBI), but advanced HS with TBI will make GCS unreliable until macro-hemodynamic is normalized and micro-hemodynamics is not at risk either (coagulopathy and osmolarity). Finally, in HS without TBI the level of consciousness depends on systemic circulation hypoxemia, without the locoregional component dysregulation of flow present in moderate or severe TBI. To use GCS in classifying HS in the absence of TBI is improper. The simple AVPU system suffices to indicate deterioration of level of consciousness due to systemic hypoxemia and is assessed at once!

As a matter of fact, only <10% of patients with HS can be correctly categorized under ATLS classification.[9]

Adding the base deficit alias negative base excess (NBE) in the ATLS classification only makes it more fancy, but it stays as impractical as before; and its acceptance by a European consortium does not make it more right either.[6,7]

At a closer scrutiny, Mutschler’s integration has fallacies in several crucial points.[13] (I) Vasopressors were used in class 1 and class 2. It looks quite a significant overtreatment for a class 1, classified as no shock, or class 2 classified as mild HS! (II) To describe class I as no shock is a contradiction in terms, why then to put it as category of a classification of shock?[9] (III) To classify as moderate class 3 h is erroneous and quite reductive.

Hypotensive shock, which means fluid-resistant shock, is a life-threatening situation calling for rushing to OT for quick source control to prevent cardiovascular of brain injuries or death by exsanguination. Persisting hypotension in HS has a 54% predictive mortality risk.[9] The dynamic is one where the arteriolar system has been overwhelmed or has failed to compensate blood loss satisfactorily at safe level. It cannot be possibly labeled as “moderate!” (IV) The use of vasopressors in this category to supply a failing hypotensive resuscitation does not change the shock category, but slows deterioration towards exsanguination! (V) Similarly, I would not define class 4 as “severe,” rather as “impending cardiac arrest.” (VI) The different values of NBE were not monitored continuously real time during the shock, but random both in ED and in intensive care unit (ICU). The lack of a correlative and dynamic synchronicity between BD and shock categories makes the BD addendum not a crucial tool. The major drawback of parameters such as BE and LA is the lack of synchronicity with the actual tissues perfusion and the need to do repeated assays through a peripheral or central venous line.[8,10-13] Shock is a changing dynamic, and static measurements of BD per se say nothing. There is dys-synchrony in speed between the installing of hypotension and the rising of base deficit or lactate levels.[14] The basic error is trying to fit variables in a classification assumed valid, like fitting a piece in a puzzle. [Accessory File – Fig 2].

In a sharp editorial, Wiles displays brilliantly the ATLS programs rigidity, deficiencies and errors.[15]

The Hannover/Leeds groups (Pape and Giannoudis) had already developed a set of sensible guidelines to aid decision-making in polytrauma cases, with a classification similar to the ATLS one, but with addition of “soft tissues/orthopedic injuries” into the classification, and the decision-making as far as the orthopedic injuries either as “damage control orthopedics” or as “early total care.”[16] Despite containing a superior semantic than the one of ATLS in the terminology of the four key classification words proposed (stable, borderline, unstable, in extremis), it however calls for the same criticism of the ATLS one as far as applicability, timely implementation and retrospective evaluation. Their classification englobes the ATLS one, lactate and BE levels, and coagulation factors levels. It contains errors in the variables of blood pressure – presumably the systolic, the temperatures, and the number of blood units. The number of blood units required cannot be a reliable parameter for decision-making. Temperatures assigned to each category do not reflect reality as critical/in extremis shock alias impending CA by exsanguination can occur with internal temperatures of 35°C–34°C if blood loss is faster than the installing of metabolic hypothermia. Moreover, a systolic <70 mm Hg (50–60 mm Hg) can only be elicited with direct arterial line direct measurements, as at around 70 mm Hg no peripheral pulse is palpable and the patient has collapsed or about to.

The polytrauma classification has though a merit in drawing attention on the posttraumatic inflammatory response/systemic
inflammatory response (SIR), invariably present in blunt trauma with orthopedics and soft-tissues trauma, as cause of second hit of morbidity and mortality. In penetrating trauma, in fact, the inflammatory cascade gets lost out of circulation with the breech of the vascular system.[17] The classification was clearly biased by the authoritative expertise of the authors in orthopedics and soft-tissues trauma often accompanying traumatic HS. Another positive point is the subdivision of patients into a clear relation between classification and decision-making. According to the authors, those in extremis and unstable patients are managed utilizing a damage control approach. Stable patients can be managed using standard protocols; patients in borderline group have been stabilized by resuscitation and have responded to intervention and become stable. To have introduced the concept of dynamic appraisal of the trauma patient in the reversibility of borderline patients, a dynamic appraisal that the statutory ATLS classification, more rigid, does not contemplate or suggest, is another point in favor of the Hannover/Leeds classification.[16] [Accessory File – Fig 3].

The Physiological Classification

A new classification [Table 1], which may well be called as the “physiological HS classification” or “therapeutic HS classification,” was proposed since 2010, following the new developments on microcirculation and an already going-on sensible praxis among some trauma surgeons.[18] It bases on a decision-making that keeps in account hard practice, basic physiological considerations such as the significance of fluid-blood resistant hypotension, body natural hemostatic mechanisms, the right definition of shock, and the relevance that hemorrhage-triggered ischemia-reperfusion (IR) and SIR have in critical illness scenarios as secondary insult from ischemia. The diriment linking point of the classification is whether in a hypotensive HS is present ab initio an “unstable,” not stabilizable, “severe shock” i.e., a persisting shock with a not fluid-responsive hypotension or a short-term stabilization not more than 20–30 min duration, or not [Accessory File – Figure 4] See Below.

Hypotension is consistently present only with 30% of TBV loss and can be inconstant between 20 and 30% values.

An indirect proof of the significance of a 30% TBV loss as the level always manifesting clinically significant hypotension is in hemotherax management. In an adult, 1.5 L of blood loss from a thoracic drain, exactly around 30% of TBV, even if the blood loss extends within the 24 h, signals the need of a thoracotomy over conservative management.[19]

Two other studies have confirmed the level of 30% of TBV loss, around 1.5 L in a 70 kg average patient, as a level in which hypotension is unexceptionally present and DCS is indicated.[20,21]

At some stage of a progressing hypoxemia, the arteriolar endothelium itself, which engineers the dynamics of exchange with the distal tissues, goes in dysfunction, due to inherent hypoxia from systemic hypoxemia.[22-24] The initial dysfunction can still be compensated by iatrogenic vasoconstriction. Shock progression inevitably leads to resistance to catecholamines and subsequently to a cardiac or a neurological event and eventually to cardiac event by exsanguination.[10]

Systolic blood pressure (SBP) in the absence of interfering variables such as drugs, heart disease, and hypertension in elderly patients, can be relied on for classification, being a direct variable of CO. For hemodynamic stabilization to be considered established, besides normal BP and reverse trend of tachycardia, patients must be seen with normal or improved complexion, mental status, urinary output, and comforting indirect signs of perfusion such as capillary refilling, mottling disappearance, PO₂, and SO₂ adjustment toward normalization.[10]

Rationale, Background

No critical care situation, whether cardiogenic shock, septic shock, or HS, can disregard three fundamental physiological concepts: fluid responsiveness test, the cardiac/circulatory reserve, and the microcirculation, specifically the arteriolar system.

Cardiac/circulatory reserve

The cardiac output (CO) determines the amount of oxygen delivered to tissues and is in direct relationship with venous return according to Starling Law.[25] The functionality of myocardium is affected not only by venous return but also by myocardial contractility, wall tension and by afterload, which is the sum of the resistance of all arterioles as manifested by aortic wall tension during systole against which the heart has to produce a stroke volume and is measured by the mean arterial pressure (MAP). Myocardial contractility is also affected by the presence of structural damage, rhythm disorders and valve disease. The effective circulating blood volume, also known as venous return, determines CO, due to its direct relationship with myocardial compliance and contractility. In physiological conditions and normal myocardium, the heart must pump all the blood it receives back out and cannot pump any more than it receives. The downstream pressure produced by the venous return is the right atrial pressure (RAP). CO is determined by this pressures gradient between MAP and RAP.[26,27]

Cardiac reserve, which in the case of a HS is better defined by the term circulatory reserve, is the maximum quantity of blood that can be pumped above basal normal level during exercise or to compensate deficits within physiological limits. The lower is or becomes the myocardial functional reserve, i.e., the healthy part of myocardium capable to answer to venous return variations during diastole with an increase of contractility according to Frank–Starling law, higher the chances of shock overlapping failure of the pump. This occurs because decreased compliance leads to increased left/right-ventricular end-diastolic pressures causing increased wall tension and increased oxygen consumption (VO₂), which in turn decreases the CO.[26,29] Simply, as put also
by Convertino words, any physiologic compensatory mechanism (e.g., tachycardia and vasoconstriction) has a finite maximal response to any specific physiologic stressor (e.g., hemorrhage): compensation “reserve” is the difference between the maximal response and the baseline state. The term circulatory reserve encompasses comprehensively this crucial, ominous, essential, not disregardable, and concept of critical care.

CO response is the most reliable parameter to use to measure cardiac/circulatory reserve as in direct relationship with the venous return. CO measured continuously with trans-thoracic echocardiogram (TTE) following fluid challenge/s in 5–10 min is a simple method to use at bedside. Patients should undergo CO echocardiography monitoring for at least a 20 in period. TTE needs skills and experience to be very accurate, but remains the best available means to monitor CO. Clinical observation for the same time is practically what is commonly used, measuring the systolic pressure as a direct variable of CO, and correlating it with the general clinical picture. In the absence of myocardial or valves disease, hypertension in elderly especially with co-presence of a TBI, or of interfering drugs, the SBP response to fluid load in patients with normal circulatory/cardiac reserve can be relied and accepted as rough guide in lieu of CO. If after 20–30 min the CO, its direct variable the systolic pressure and its indirectly related tachycardia, have not improved and maintained stability, it can be assumed the body reserve capacity is not enough to allow a reflection on decision making other than rushing to theater for rapid source control.

### Fluid responsiveness test

The dynamics of fluid challenge in septic shock have been well studied by Cecconi, Bennett, Aya et al. The principle behind the fluid challenge test is that by giving a small amount of fluid in a short period of time, the clinician can assess whether the patient has a preload reserve that can be used to increase the stroke volume and CO with further fluids. To mitigate against the risk of fluid overload in those who do not require additional intra vascular volume, the smallest volume that provides an effective challenge of the cardiovascular system should be used.

A change in the pressure gradient of venous return, defined as the difference between the mean systemic filling pressure (Pmsf) and central venous pressure (CVP) following a fluid challenge, is seen in responders but not in nonresponders. In the nonresponders, the increase in Pmsf is mirrored by an increase in CVP. In those that respond, the maximal change in CO is seen 1 min after completion of the fluid challenge. Pmsf is the measurement of the pressure when there is no flow in the vessels like in a circulatory arrest.

Intravascular volumes are well divided in “stressing volume” and “unstressing volume” with reference to the vessels wall tension. The unstressing volume fills the vessels but does not generate any pressure. The stressing volume causes stretch of the vessel walls and increases the pressure within the vessels. If an effective fluid challenge is given, it will, at least transiently, increase the stressing volume and cause a rise in Pmsf. This increases cardiac preload, which ultimately increases CO in the preload-responsive patients according to Frank–Starling principle. If a fluid challenge is given, which is effective in significantly increasing Pmsf and no subsequent increase in CO is seen, the patient is labeled as nonresponsive.

In normovolemic conditions like in a septic shock, if the patient is fluid responsive, i.e., has a functional arteriolar system, an effective fluid challenge will result in a significant increase, of more than 10%, in the stroke volume or CO. The increase in CO is a transient response; a return to baseline values is seen 10 min postfluid administration.

The optimal amount of fluid challenge test in septic shock is ≥4 ml/kg, the amount incidentally used in repeated doses for hypotensive resuscitation in HS.

There is a substantial difference between a fluid challenge in an inflammatory or distributive shock and in a hemorrhagic one, and that is normovolemia in one and hypovolemia in the other one. Despite the differences of dynamics between the septic shock, where the fluid responsiveness test, more appropriately specified as fluid challenge test, has been extensively developed, and the HS, in terms of volemia, the same principle and rationale, with due modification, can be applied and reliably standardized in the management of HS.

The test fluid used should be one facilitating microcirculation flow dynamics. In experimental conditions, hypertonic saline (HTS) or synthetic colloids combinations (hyperosmotic-hyperviscous-solutions, HTS, or RL combined with alginates, and conjugated albumin solutions) have shown to represent an optimal choice for microcirculation dynamics. HTS would be the optimal fluid in HS combined with TBI but cannot be given more than 375 ml/h. Hetastarch, despite its deleterious effect on kidneys, is preferred in some military schools. A plasma formulation can also be used as for the beneficial role of plasma oncotic and viscosity properties. Crystalloids are probably better to be avoided due to the proven deleterious effects on hypotensive not stabilized HS.

### Table 1: Physiological classification of hemorrhagic shock

| Stage | Description |
|-------|-------------|
| I     | Mild/Stable: only skin signs and tachycardia |
| II    | Moderate/Stabilized: shock responsive to fluid test load |
| III   | Hypotensive shock transient responder for <20-30 min OR Hypotensive shock not responsive to fluid test load of 500 ml x 2 |
| IV    | Shock with heart and brain ischemic signs or TBV loss of ≥ 40% |
| V     | Cardiac Arrest by Exsanguination |

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Micro-circulation – The arteriolar system

Any approach to critical care topics like shock, or HS, cannot not emphasize the role of the arteriolar system, the microcirculation gate-keeping system, controlling oxygen delivery, and distribution. Microcirculation is the sancta santorum of life, where we live and die. Macro-circulation is only a reservoir a blood tank for microcirculation and has its only crucial and essential role only in the filling microcirculation, calling and allowing blood according to its requirements.

A fact emphasizes the importance of an approach more oriented toward microcirculation in the management to the management of HS or any shock in ICU with the aim to prevent morbidity and mortality: the scarce prediction and monitoring value of macro-hemodynamics variables, among which blood loss. Often in ICU macro-hemodynamics variables are seen within normal range and stabilized but patients still deteriorate and die with reassuring values.[10] By failing to address and consider the crucial and essential role of the microcirculation/tissues interaction, hence DO₂ and VO₂, the presence of a subclinical or cryptic shock, which in the setting of HS means ischemia-reperfusion toxaemia (IRT) leading to second hit MODS/MOF, gets overlooked and downplayed. Instead, it is exactly what is leading the patient to death in the face of reassuring macro-hemodynamics variables.

Arterioles are the gate-keepers of microcirculation and the last frontier of intervention we have available to support and save patients from exsanguination. An inadequate or failing arteriolar system, unequivocally signals progressive not compensated or compensable shock, eventually leading, in a scenario of late or inadequate or omitted source control, to direct death from cardiac arrest from insufficient venous return, death through irreversible shock, or exitus by MOF often following IRT if source control was late or inadequate. Being crucial traffic controllers and an obligatory pit stop at the border macro-microcirculation, arterioles are responsible for avoiding shock progression.

**Clinical Correlations and Implications**

Only an integrated combination of (i) ScvO₂, (ii) in vivo microcirculation visualization, (iii) continuous CO monitoring through TTE within the clinical context, can predict the direction of macro and micro-dynamics of a progressing hemorrhage.

In hypovolemia, like in a hypotensive HS, fluid challenge should be given in volumes sufficient enough to bring first the V/P ratio to a less negative level than the one occurring once hypotension installs, in the same time keeping the ratio not close to the unity in case this would counteract the physiological hemostatic mechanisms. Due to hypovolemia, not present in the septic shock situation, only by increasing the mean systemic filling pressure (Pmsf) we will know if the challenge-test can be relied on in the appraisal of a HS. The aim of a fluid challenge in a progressing hypotensive shock is to determine whether the blood loss has been controlled by the physiological mechanisms and a functional arteriolar system or is progressing and and we are dealing with an uncontrolled hemorrhage.[18]

To restore the blood volume loss that had produced hypotension, which in an adult is at least 20% of TBV, is therefore the first step. More than that amount in an adult, for example 1.5 L, which equals approximately to 30% of TBV and is the amount that if lost gives consistently hypotension, might actually increase bleeding by counteracting the physiological hemostatic mechanisms. Consequently, it can be seen as reasonable and acceptable tactics the following order of steps. (1) Give a 500 mL bolus of fluids within 5 minutes and repeat it within next 5 min if no hemodynamic changes are seen, specifically normalization of SBP and inverse trend of tachycardia. (2) Observe possible meaningful effects on CO/SBP. (3) Persisting hypotension calls for rushing to theatre and rapid source control; if instead systolic and tachycardia improve, wait another 10-20 min to see if the effect on CO and SBP remains stable.

This empiric dosage has also been indirectly confirmed as correct amount for bolus for the average adult of ±70 Kg in a study where an increased mortality was seen with >500 ml bolus prn in patients with blunt trauma without prehospital hypotension, compared to a prehospital hypotensive patients group.[37] Incidentally, only recently ATLS®, without giving a rationale for it, have bowed to the overwhelming of evidence of the last two decades or so, and recommended an initial fluid load not higher than 1 L from the previous recommendation of 2 L.[1]

Practically, with the information obtained by the test, the decision will stay between rushing to theatre or indulging in further assessment but only with essential or relevant investigations, as long as preparedness for rapid GA/DCS are on standby and the patient is operated anyhow within 4-6 hours from injury [Table 2].

A relevant advantage of the “Physiological Classification” is that the “mild or moderate HS,” or “stable and borderline,” stage of shock,[16,18] identifies a level of derangement compensated enough to safely allow diagnostic and therapeutic interventions such as laparoscopy, thoracoscopy, and angiography.

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**Table 2: Therapeutic classification of hemorrhagic shock**

| Stage | Classification | Criteria |
|-------|----------------|---------|
| Stage I: Stable, Mild, Non-Hypotensive | No active bleeding, patients can tolerate delays to assess shock (clotting tests), physical examination, and monitor V & P ratio. | V/P ratio ≤ 0.3, SBP ≥ 90 mmHg, HR ≤ 100 bpm, CVP ≤ 8 mmHg, and Pmsf ≥ 13 mmHg. |
| Stage II: Stabilized, Compensated, Moderate Hypotensive | Moderate level of derangement, patients tolerate delays to assess shock (clotting tests), physical examination, and monitor V & P ratio. | V/P ratio ≤ 0.3, SBP ≥ 90 mmHg, HR ≤ 100 bpm, CVP ≤ 8 mmHg, and Pmsf ≥ 13 mmHg. |
| Stage III: Hypotensive, Unstable, Severe, or Incompensated Progressive | Severe level of derangement, patients require immediate source control, rapid fluid resuscitation, and immediate source control to prevent MOF. | V/P ratio ≤ 0.3, SBP < 60 mmHg, HR > 100 bpm, CVP < 8 mmHg, and Pmsf < 13 mmHg. |
| Stage IV: Critical, Extreme Shock, Expanding Cardiac Arrest | Exsanguination. | Fluid challenge, rapid source control, and rapid GA/DCS. |

**Notes:**
- NOM: Non-Operative Management, PRC: Packed Red Cells, DCA/DCS: Damage Control Anesthesia/Damage Control Surgery, CVL: Central Venous Line, DCR: Damage Control Resuscitation, EPR/CAT: Emergency Preservation Resuscitation/Cardiac Arrest Trauma.

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**Image Reference:**
- Preservation Resuscitation/Cardiac Arrest Trauma
- Venous Line, DCR: Damage Control Resuscitation, EPR/CAT: Emergency Damage Control Anesthesia/Damage Control Surgery, CVL: Central Nom: Non-Operative Management, PRC: Packed Red Cells, DCA/DCS: Damage Control Anesthesia/Damage Control Surgery, CVL: Central Venous Line, DCR: Damage Control Resuscitation, EPR/CAT: Emergency Preservation Resuscitation/Cardiac Arrest Trauma.
Even in the borderline stabilized patients such techniques can be done safely, provided preparations for a stand-by crush intervention are in act. In the stable compensated shocks, whole blood can be spared and “crystalloids and RBC only” used for transfusion.\[18\]

Another crucial indirect corollary of the classification is that persistent refractory hypotension can be reliably used as criterion for DCS, because indicates inadequacy or failure of the micro-circulation arteriolar-gate mechanism.

Indoors, fluid responsiveness test is necessary to distinguish a situation in which a functional, not yet unduly stressed, arteriolar system response has stopped the physiological downfall of a hypotensive shock, by restoring normo-tension and reverse tachycardia trend, due to the facility to bring the patient to theatre as soon as possible for rapid source control. Outdoors, fluid responsiveness test as such should not be done as for the unknown risk of worsening the hemodynamic equilibrium in a context where the patient cannot be taken at once to theatre.

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There are no conflicts of interest.

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**Supplementary File**

Other classifications of haemorrhagic shock

**Accessory File – Fig 1**

Holcroft and ATLS Classifications

| Parameter                  | Class I | Class II (mild) | Class III (moderate) | Class IV (severe) |
|----------------------------|---------|------------------|----------------------|-------------------|
| Approximate blood loss (%) | <15     | 15–30            | 31–40               | >40               |
| Heart rate                 | ↔       | ↔/↑              | ↑                    | ↑/↑↑              |
| Blood pressure             | ↔       | ↔/↓              | ↓                    | ↓                 |
| Pulse pressure             | ↔       | ↓                | ↓                    | ↓                 |
| Respiratory rate           | ↔       | ↔/↑              | ↑                    | ↑                 |
| Urine output               | ↔       | ↔/↓              | ↓                    | ↓                 |
| Glasgow coma scale score   | ↔       | ↔/↓              | ↓                    | ↓                 |
| Base excess* mEq/L         | 0−2     | −2−6             | −6−10                | ≤−10              |

*Blood diverted towards noble organs in a reverse hierarchy response; **Hypotension is consistently present when >30% TBV loss. It may or may not be present with blood loss of <30% TBV. Hypotension signals decompensation; ***Persisting Tachycardia with normalised systolic after fluid load signals partial compensation (stably unstable); ****Persisting Tachycardia and hypotension after fluid load signals severe life threatening physiology (unstably unstable); BV: Blood volume; ATLS: Advanced trauma life support; TBV: Total blood volume

**Accessory File – Fig 2**

ATLS Classification of Haemorrhagic Shock (+ MUTSCHLER Integration)

American College of Surgeons Advanced Trauma Life Support (ATLS) classification of blood loss, based on initial patient presentation. Signs and symptoms of haemorrhage by class.

| Parameter                  | Class I | Class II (mild) | Class III (moderate) | Class IV (severe) |
|----------------------------|---------|------------------|----------------------|-------------------|
| Need for blood products    | Monitor | Possible         | Yes                  | Massive transfusion protocol |

**Accessory File – Fig 3**

Polytrauma Shock Classification by Pape & Giannoudis

| Parameter                  | Stable (Grade I) | Borderline (Grade II) | Unstable (Grade III) | In Extremis (Grade IV) |
|----------------------------|------------------|-----------------------|----------------------|------------------------|
| Shock                      | 100 or more      | 80–100                | 60–90                | <50–60                 |
| Blood units (2 h)          | 2–8              | 5–15                  | >15                  |                        |
| Lactate levels             | normal range     | approximately 2.5     | >2.5                 | severe acidosis        |
| Base deficit (mmol/L)      | no data          | no data               | >6–18                |                        |
| ATLS classification        | II–III           | III–IV                | IV                   |                        |
| Coagulation                | >100,000         | 90,000–110,000        | <70,000–90,000       | <70,000                |
| Platelet count (μg/mL)     | 70–90            | 50–70                 | 50–70                |                        |
| Factor II and V (%)        | 90–100           | approximately 1       | <1                   |                        |
| Fibrinogen (g/dl)          | >1               | normal range          | abnormal DIC         |                        |
| D-Dimer                    | normal range     | abnormal              | DIC                  |                        |
| Temperature                | >34°C            | 33°C–35°C             | 30°C–32°C            | 30°C or less           |
| Soft-tissue injuries       | Lung function; PaO₂/FiO₂ >350 | 300 | 200–300 | <200 |
| Chest trauma score; AIS    | AIS I or II      | AIS 2 or more         | AIS 2 or more        | AIS 3 of more          |
| Thoracic trauma score; TTS | I                 | II                    | III                  | IV                     |
| Abdominal trauma (Moore)   | 0                 | ≤III                  | III or >III          |                        |
| Pelvic trauma (AO class)   | A type (AO)      | B or C                | C                    | C (crush, rollover abd.) |
| Extremities                | AIS I–II         | AIS II–III            | AIS III–IV           | Crush, rollover extrem. |
| Surgical strategy          | Damage control (DCO) or | DCO if uncertain      | DCO if stable        | DCO                    |
| (Fig. 2)                   | Definitive surgery (ETC) | ETC                   | ETC                  |                        |
### Accessory File – Fig 4
Physiological classification of haemorrhagic shock (Ref 18)

| Level   | Description                                                                 |
|---------|-----------------------------------------------------------------------------|
| Critical HS | Shock with heart and brain involvement or > 40% TBV loss (impending CV collapse) → Stand-by surgery for source control |
| Severe HS  | Shock with hypotension not responding to blood/fluid load-test (unstably unstable) → Rapid surgery for source control |
| Moderate/ Mild HS | Moderate shock is hypotensive shock responding with normotension and reverse tachycardia trend to blood/fluid overload (unstably stable); mild shock is normotensive tachycardic from start → Investigate, Ponder surgery, Interventional radiology/ Non-operative intervention |

*Hypotension may occur at ≥ 20% and is always present at ≥ 30% TBV loss; **By response is meant reverse tachycardia trend and normalization of pressure; HS: Haemorrhagic Shock; TBV: Total Blood Volume; CV: Cardiovascular