BURNS 47 (2021) 1730–1738

Available online at www.sciencedirect.com

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A simplified fluid resuscitation formula for burns in mass casualty scenarios: Analysis of the consensus recommendation from the WHO Emergency Medical Teams Technical Working Group on Burns

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ARTICLE INFO

Article history:
Accepted 16 February 2021

Keywords:
Mass casualty

ABSTRACT

Background: Burn fluid resuscitation guidelines have not specifically addressed mass casualty with resource limited situations, except for oral rehydration for burns below 40% total body surface area (TBSA). The World Health Organization Technical Working Group on Burns (TWGB) recommends an initial fluid rate of 100 mL/kg/24 h, either orally or intravenously, beyond 20% TBSA burned. We aimed to compare this formula with current guidelines.

Methods: The TWGB formula was numerically compared with 2–4 mL/kg/%TBSA for adults and the Galveston formula for children.

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https://doi.org/10.1016/j.burns.2021.02.022

Burns
Fluid resuscitation
Mass burn casualty incidents
Prehospital care
Emergency Medical Teams

Results: In adults, the TWGB formula estimated fluid volumes within the range of current guidelines for burns between 25 and 50% TBSA, and a maximal 20 mL/kg/24 h difference in the 20–25% and the 50–60% TBSA ranges. In children, estimated resuscitation volumes between 20 and 60% TBSA approximated estimations by the Galveston formula, but only partially compensated for maintenance fluids. Beyond 60% TBSA, the TWGB formula underestimated fluid to be given in all age groups.
Conclusion: The TWGB formula for mass burn casualties may enable appropriate fluid resuscitation for most salvageable burned patients in disasters. This simple formula is easy to implement. It should simplify patient management including transfers, reduce the risk of early complications, and thereby optimize disaster response, provided that tailored resuscitation is given whenever specialized care becomes available.

1. Background

Early fluid resuscitation is a fundamental part of initial burn care and crucial to survivability of major burns. Although many different formulae have been proposed to estimate fluids to be given in severely burned patients, the original Parkland [1] and Evans [2] / Brooke [3] formulae still prevail in current consensus guidelines of 2 to 4 mL/kg body weight/% total body surface area burned (%TBSA) [4–6], respectively as their upper and lower range. This consensus formula, as proposed in multiple current guidelines, is actually a range. This might account for the differences observed in their clinical use and for the difficulty of achieving a strong consensus [7]. Notably, the aforementioned resuscitation formulae were all based on retrospective analysis of favorable outcomes and none have been validated in larger randomized controlled trials [6,8]. Initially these resuscitation formulae were not promoted as rigorous treatment plans, but rather as starting points from which clinical judgment and hemodynamic monitoring render adjustments [5,6]. Though fluid resuscitation formulae are helpful as practice guidelines, the expertise to monitor and adjust a fluid regimen might not be readily available in mass burn casualty situations [9]. In fact, the challenging nature of balancing these adjustments in daily burn center routine has been pointed out by the risks of over-resuscitation and resulting fluid creep [10–12]. The possible difficulties of adhering to resuscitation guidelines in austere conditions have also been recognized [9,13,14]. This has led to recommendations on fluid resuscitation *per os* using Oral Rehydration Solution (ORS) up to 40% TBSA, but not to new recommendations on fluid resuscitation formulae [15].

As part of its Emergency Medical Teams (EMT) initiative to set minimal standards of care in disaster and emergency situations [16], the World Health Organization (WHO) appointed a Technical Working Group on Burns (TWGB) to develop specific burn recommendations within the EMT framework. The resulting consensus recommendations for burn care in mass casualty incidents provide comprehensive guidelines from on-scene management to rehabilitation [17].

In its consensus recommendation #8a, the WHO EMT Technical Working Group on Burns (TWGB) has proposed a simplified resuscitation formula exclusively dedicated to mass burn casualty situations, to be used only until specialized care becomes available [17]. The TWGB recommends 100 mL/kg/24 h as the fluid resuscitation formula for any burn extending more than 20% of total body surface area (%TBSA), either orally or intravenously, with no specific resuscitation below 20% TBSA. Details are given in Table 1. TWGB recommendation #8b also stresses that fluid status of the patient should be assessed regularly and fluid regime adjusted accordingly, and the rationale of the recommendations explicitly warns against strictly formulaic adherence to the proposed simplified fluid rate [17].

The aim of this article is to analyze how the TWGB simplified fluid resuscitation formula compares with existing guideline formulae using simple numerical computations, in order to discuss its feasibility, risks and expected benefits in the context of mass burn casualty situations.

Table 1 – TWGB simplified fluid resuscitation formula for burns in mass casualty situations.

Body surface area burned (%TBSA)	<20 %TBSA	20 to 40% TBSA	>40% TBSA
Fluid resuscitation rate	*Ad libitum*	**100 mL/kg/24 h** (consider the need for more fluids for children ≤ 15 kg)	
Resuscitation route and type of fluids	Oral fluids to thirst (no i.v. fluid recommended)	**Oral rehydration solution (ORS) *p.o.*** as soon as practicable (consider i.v. fluids as appropriate)	**Crystalloids *i.v.*** (and drink as able)

Recommendation #8a by the WHO EMT Technical Working Group on Burns (TWGB) [17]. *p.o.* = *per os*, *i.v.* = intravenous.

2. Methods

The TWGB fluid resuscitation formula for mass burn casualties was compared with usual burned surface area-driven formulae using simple numerical computations and their graphical representations. The comparison was conducted using R software version 3.6.3 with lattice and plotly packages (R Foundation for Statistical Computing, Vienna, Austria; https://cran.r-project.org).

In adults, resuscitation fluid estimates were compared between the TWGB formula and the existing guidelines consensus formula of 2 to 4 mL/kg body weight/% total body surface area (%TBSA) burned [4–6].

In children, resuscitation fluid estimates were compared between the TWGB formula and the Galveston formula, which states resuscitation fluids 5000 mL/m^2 body surface area (BSA) burned/24 h, plus maintenance fluids 2000 mL/m^2 BSA/24 h [18]. Since the Galveston formula uses body surface area as its actual reference, this parameter was derived from weight using Costeff formula: BSA = (4 × W + 7)/(W + 90), where BSA denotes body surface area (m^2) and W denotes weight (kg) [19].

No further statistical analysis was considered relevant to the study approach.

3. Results

In adults, comparison of resuscitation fluid estimates between the TWGB fluid resuscitation formula for mass burn casualties [17] and the existing guidelines consensus formula of 2 to 4 mL/kg/ %TBSA [4–6] were in agreement in the 25–50 %TBSA range, where TWGB estimated fluid to be given fell within the range of the consensus formula (Fig. 1). The TWGB recommendation gave predictions above yet close to the upper range of existing guidelines consensus formula between 20 and 25% TBSA, and below yet close to its lower range in burns between 50 and 60% TBSA, with a difference between 0 and 20 mL/kg/24 h in both cases. The TWGB formula increasingly underestimated resuscitation fluid estimates in burns larger than 60% TBSA.

For children between 5 and 45 kg, a tridimensional comparison view of resuscitation fluid estimates for the first 24 h depending on %TBSA burned and body weight is shown in Fig. 2, as calculated by the TWGB fluid resuscitation formula for mass burn casualties [17] and by the Galveston formula [18]. The corresponding exhaustive and interactive 3D representation is provided as online Supplementary Fig. S1. It is viewable with any web browser with javascript enabled, and allows to rotate views in all directions and to display the associated values of %TBSA burned, weight and initial resuscitation fluid estimates by simply hovering the mouse cursor over the desired surface. Fig. 3 shows the same comparison for children of fixed weights between 5 and 30 kg. Thus, the corresponding graphs in Fig. 3 are cross-sections of the tridimensional surfaces displayed in Fig. 2 and online Supplementary Fig. S1.

In the 20–60% TBSA range in this patient population, agreement between both approaches was poorer than in adults. Overall, the TWGB formula underestimated fluid to be given in children. It predicted fluid volumes that fell

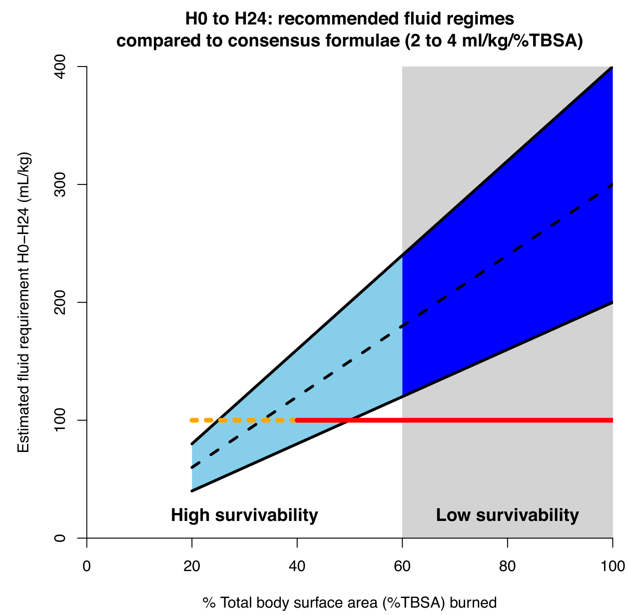

Fig. 1 – Comparison of TWGB fluid resuscitation formula for mass burn casualties with single patient consensus formula in adults.
Consensus formula: 2–4 mL/kg body weight/% total body surface area burned (%TBSA)/24 h (blue area: corresponding range; dotted midline: mean value of 3 mL/kg/ %TBSA). TWGB recommended fluid regimes: 100 mL/kg body weight/24 h, Oral Rehydration Solution *per os* between 20 and 40% TBSA (orange dotted line), intravenous crystalloids above 40 % TBSA (red solid line). Shaded area, above 60 %TBSA, denotes most severe burns of low survivability in mass burn casualty situations with lower resource environments. (For interpretation of the references to color in the figure legend, the reader is referred to the web version of this article.)

approximately between the resuscitation fluids only and the total resuscitation fluid estimates when including both maintenance and resuscitation in children 20 kg and above. In children 15 kg and below, the simplified TWGB formula approximately matched current standards if only resuscitation fluids were considered, but resuscitation fluid estimates were underestimated if compared to the total volumes for resuscitation and maintenance. In accordance with the findings in adult calculation, the TWGB formula increasingly underestimated resuscitation fluid estimates in children with burns larger than 60% TBSA.

4. Discussion

The present study found, based on simple numerical computations, that the TWGB fluid resuscitation formula for mass burn casualties [17] agrees with the existing guidelines consensus formula of 2 to 4 mL/kg/ %TBSA [4–6] in the 25–50 %TBSA range in adults. There is a mild discrepancy when this range is extended to 20–60 %TBSA. In children, the TWGB formula does not account for necessary supplementation with maintenance fluids, especially up to 15 kg, when compared with Galveston formula [18]. In burns extending over 60 %

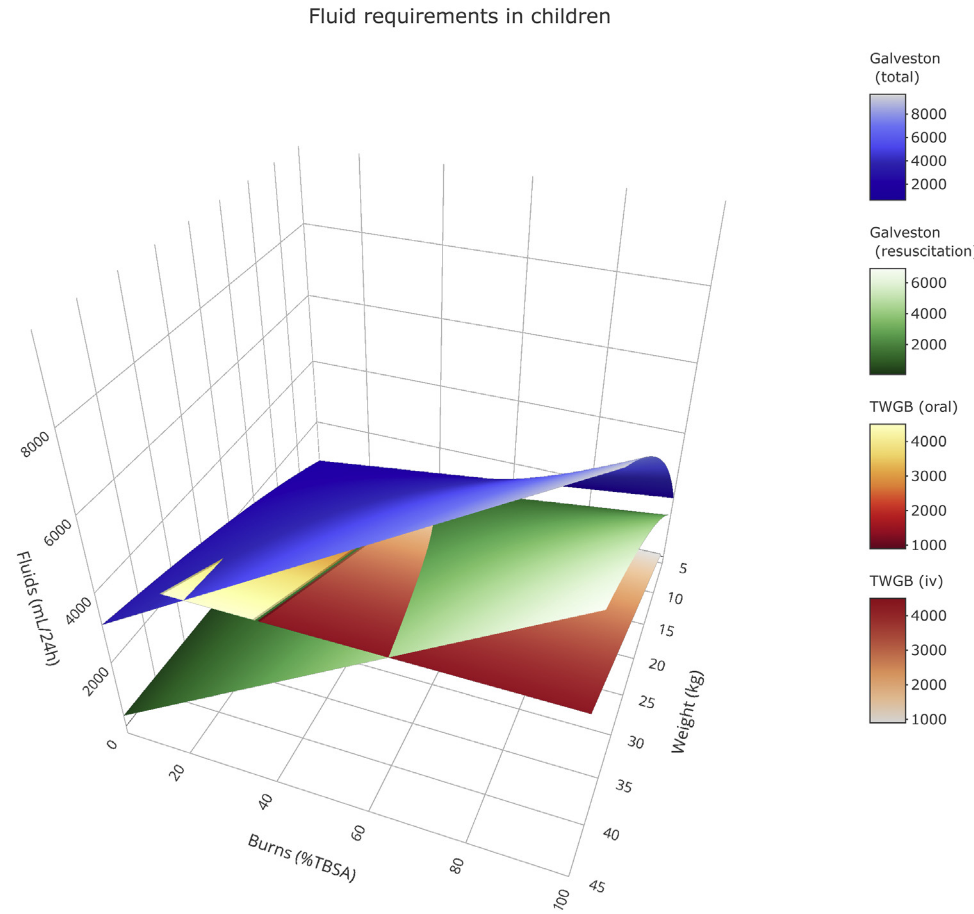

Fig. 2 – Tridimensional comparison of TWGB fluid resuscitation formula for mass burn casualties with Galveston formula in children from 5 kg to 45 kg.
Galveston formula: resuscitation fluids 5000 mL/m^2 body surface area (BSA) burned/24 h (green surface), plus maintenance fluids 2000 mL/m^2 BSA/24 h (total: blue surface). TWGB recommended fluid regimes: 100 mL/kg body weight/24 h, Oral Rehydration Solution *per os* between 20 and 40% TBSA (orange-yellow surface), intravenous crystalloids above 40 %TBSA (red surface). Full interactive version of this tridimensional comparison available as online Supplementary Fig. S1. (For interpretation of the references to color in the figure legend, the reader is referred to the web version of this article.)

TBSA, the TWGB formula largely underestimates resuscitation fluid estimates in all age groups.

Notably, this study was not based on simulations using historical patient samples or randomly generated ones from non-disaster databases, in order to avoid potential difficulties to extrapolate results to actual disaster-struck populations, but on simple yet exhaustive numerical comparisons of fluid resuscitation formulae.

In a mass casualty situation, the challenge is to provide the best care for the largest number when resources fall short and health care providers are overwhelmed. This involves a tradeoff of optimality for efficacy, as illustrated by the WHO EMT initiative to set minimal standards for care in disaster and emergency situations [16]. On the contrary, usual burn care guidelines set standards based on optimal resources, and provide limited guidance for adaptation to overwhelming surge conditions [4–6].

Previously available guidelines for fluid resuscitation of burns in austere conditions have limited this tradeoff to an alternative oral route of administration [9,14]. This is in line with old evidence that oral or enteral fluid resuscitation is feasible in burned patients, with fluid rates of 100–150 mL/kg body weight per 24 h of saline or sodium lactate solutions [20–22]. The excellent efficacy, safety and tolerance of WHO Oral Rehydration Solution (ORS) is well documented in infectious diarrhea [23]. Two studies of enteral resuscitation with ORS in a porcine model of 40% TBSA burns also confirmed its excellent absorption at a rate equivalent to 480 mL/kg/24 h, and its association with reduced burn-related kidney dysfunction at a rate of 70 mL/kg/24 h [24,25]. Its limitations notwithstanding, a randomized control trial of ORS resuscitation, with added oral salt, in 30 patients with 15–55% TBSA burns recently added to the available evidence of its clinical feasibility [26]. TWGB recommendation #8a therefore promotes oral resuscitation with ORS up to 40% TBSA in mass burn casualty disasters, and sticks to intravenous resuscitation with crystalloids, lactated Ringer (supplemented with dextrose in children) above 40% TBSA [17]. The further novelty of

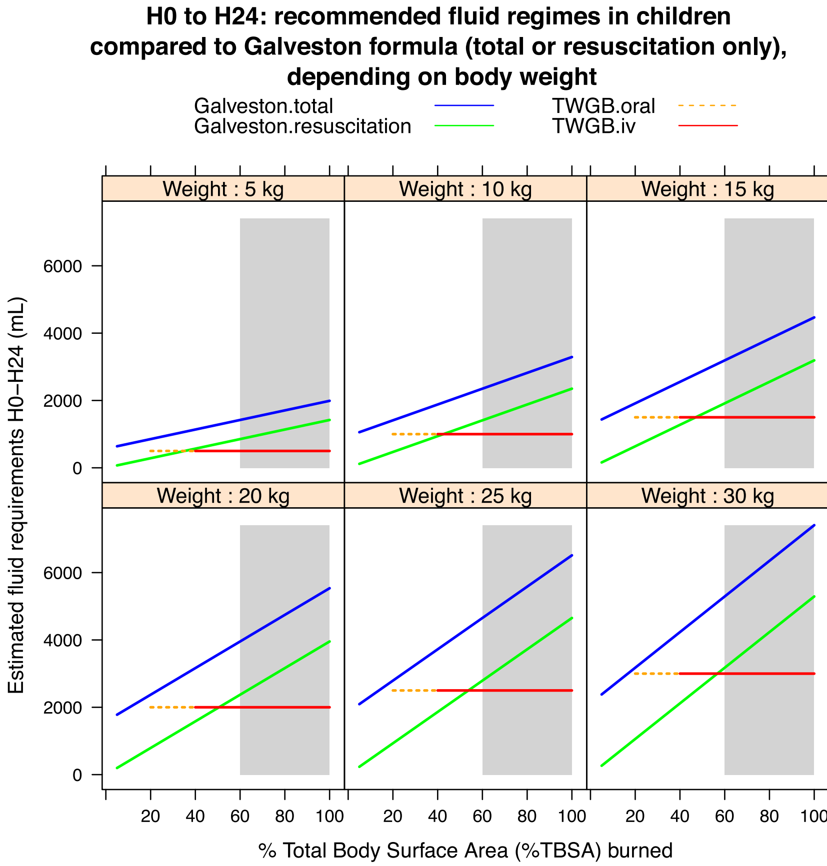

Fig. 3 – Comparison of TWGB fluid resuscitation formula for mass burn casualties with Galveston formula in children of selected fixed weights from 5 kg to 30 kg.
Galveston formula: resuscitation fluids 5000 mL/m^2 body surface area (BSA) burned/24 h (green solid line), plus maintenance fluids 2000 mL/m^2 BSA/24 h (total: blue solid line). TWGB recommended fluid regimes: 100 mL/kg body weight/24 h, Oral Rehydration Solution *per os* between 20 and 40% TBSA (orange dotted line), intravenous crystalloids above 40 %TBSA (red solid line). Shaded areas, above 60 %TBSA, denote most severe burns of low survivability in mass burn casualty situations with lower resource environments. BSA estimated from weight using Costeff formula [19]. (For interpretation of the references to color in the figure legend, the reader is referred to the web version of this article.)

the recommendation lies in the simplified, TBSA-independent fluid resuscitation rate promoted for mass casualty situations in the same optimality-efficacy tradeoff.

Many different formulae are available to calculate resuscitation fluid estimates in severely burned adult patients [1–3]. Most of them range between 2 mL/kg/ %TBSA/24 h (Evans and Brooke) and 4 mL/kg/ %TBSA/24 h (Parkland). Differences are partly explained by fluid composition: lactated Ringer with or without plasma in original formulae and albumin in more recent versions. There are other simplified approaches such as the « rule of 10»: 10 mL/h/ %TBSA, plus 100 mL/h for every 10 kg above 80 kg body weight [27]. None of these formulae was ever proven superior to others, so that existing guidelines actually promote a consensus formula, which is practically a range of 2 to 4 mL/kg/ %TBSA/24 h [4–6]. They only share one common feature, they all estimate resuscitation fluid estimates based on TBSA burned. The same holds true for children, with one supplementary feature: pediatric burn resuscitation formulae typically add maintenance fluids to meet basal estimates to burn resuscitation fluids which are calculated to compensate for the burn-related fluid losses [18,28].

TWGB recommendation #8a breaks this TBSA-driven approach. It proposes that, in a disaster situation, initial fluid resuscitation may be started with a rate that is not dependent on the estimated TBSA burned, but that this parameter only guides the route of administration, *per os* vs. intravenous. Theoretically, using this fixed fluid rate rather than usual adjustments on TBSA burned has the potential drawback to prevent the fine tuning of resuscitation to patients' individual situations. But whether this is practically relevant needs to be challenged in disaster settings.

Firstly, this fine tuning is actually fully dependent on the precision of initial TBSA assessment, the uncertainty of which on-scene is well known even in normal circumstances [29]. Inaccurate primary TBSA assessments in pre-hospital settings or referring hospitals are common [30–32]. When specifically looking at pre-hospital assessments, Hall et al. reported a 56% overall over-estimation rate in an Australian case series [33]. In disasters, as observed in Volendam in 2001, TBSA estimation on-scene is even more unreliable [34].

Secondly, the present study has shown a full agreement between fluid to be given estimated by the TWGB fixed rate and by the consensus formula range of 2–4 mL/kg/ %TBSA in adults in the 25–50%TBSA range. The maximal discrepancy of 20 mL/kg/24 h both in the 20–25% TBSA range (overestimation *vs.* the consensus range) and in the 50–60% TBSA range (underestimation) for adults is strictly equivalent to a 5–10% TBSA error in TBSA assessment. Furthermore, enteral absorption of ORS in the acute phase of burns is experimentally high, 93 $\pm$ 2,5% of enterally infused fluids in a study on a porcine model, but it is not fully complete, so that the actual fluid excess potentially resulting from the TWGB formula in the 20–25 %TBSA range is likely even lower [24]. Considering the aforementioned reported inaccuracy of TBSA assessment, initiating fluid resuscitation with the TWGB formula rather than with usual TBSA-driven formulae for patients with burns up to 60% TBSA is unlikely to cause more harm than the unavoidable TBSA assessment errors.

Thirdly, TWGB recommendations are not an incentive to ban adjustments of fluid resuscitation rates to individual situations. They only provide a simplified starting point. Whichever formula has initially been used, fluid rates need to be adjusted to the clinical response to treatment, including urine output and hemodynamic monitoring, at the earliest convenient time [4–6,35,36]. This is stressed by the TWGB in recommendation #8b, and the present discussion of the fixed fluid rate set in recommendation #8a must not lead to neglecting this cornerstone of burn care, even in disasters [17]. With this in mind, the initial use of a simplified formula makes sense.

The main two limitations of the simplified TWGB formula are for children and for patients above 60% TBSA burned. In children, the fixed, only weight-dependent, fluid rate cannot fully account for basal burn-unrelated resuscitation fluid estimates, especially in children up to 15 kg. Thus, the TWGB provided a specific additional recommendation to "consider the need for more fluids in children up to 15 kg" (Table 1 and TWGB recommendation #8a). For patients above 60% TBSA burned, under the assumptions of appropriate initial TBSA assessment and lack of subsequent fluid rate adjustment, the TWBG formula would actually put them at higher risk of marked under-resuscitation than TBSA-driven formulae, with a corresponding risk of worsened outcome. However, anticipated survivability of such large burns will be low in actual mass casualty situations [37–39], and even more so in low-resource environments [40,41]. A large Indian study on 11,196 burned patients reported a 94% overall mortality (93–100% depending on age group) for burns above 60% TBSA in daily practice, out of mass casualty situations [42]. For these most severe patients, treatment can probably be successful only if early tailored resuscitation can be achieved in conjunction with appropriate and timely surgical wound care [43–45]. Predicting resuscitation fluid volumes with formulae is also especially imprecise in these patients. For them who will have the greatest need for monitoring and fluid adjustments [6,35], strictly formula-driven resuscitation is bound to fail, so that the gap between the TWGB simplified fluid resuscitation formula and a more complex formula appears less relevant in this group.

The collective benefit-risk balance of this approach is also expected to be favorable in actual disaster situations with baseline or resulting resource scarcity, in order to spare scarce resources for patients with the highest probability of benefiting from their use. But the TWGB recommendations should apply only to such situations in which optimal, individually tailored patient management is not or not yet practicable for all casualties. The TWGB acknowledges that the appreciation of such situations can be especially difficult at the initial phase of an incident with multiple casualties, where the level of capacity saturation can be under- or overestimated. This highlights the need to determine locally appropriate thresholds to switch between optimal individual patient/casualty management systems and collective disaster management systems, in order to ensure the best possible outcome for the largest number of casualties. In areas with high-level and high-volume rescue and healthcare capacities, such thresholds can be higher, as illustrated by recently updated American Burn Association guidelines for mass casualties [39].

Additionally, under-resuscitation resulting from relative fluid restriction in the initial phase, when specialized knowledge and care are scarce, might prove beneficial or even lifesaving by reducing edema formation and thus the need for mechanical ventilation and escharotomies until such treatment is available. Burn-related systemic edema is unavoidably increased by fluid resuscitation, and it can result in a need for intubation even in a perfectly titrated single-patient resuscitation. TWGB experts supported a judicious use of permissive initial under-resuscitation in the early disaster response phase from an ABC-perspective of protecting the airway first. Importantly, this does not translate to an absence of resuscitation as the use of oral fluids are promoted for most patients. Although there is little published evidence to support this approach, permissive initial under-resuscitation was identified amongst lessons learned after repatriating burn victims to Australia from the 2002 Bali bombing. The Australian Medical Assistance Team later successfully applied 'minimal pre-hospital fluid resuscitation approach' during another burn disaster in 2009, resulting in 44 major burn victims treated for over 24 h in a remote offshore burns incident, with a publication describing the transportation of 23 of these patients over 3000 km to hospital without the need for intubation [46]. These observations match Dutch reports after the fire in Volendam in 2001, where on-scene efforts to assess TBSA burned and inhalation injuries, to triage, intubate, ventilate and resuscitate large numbers of patients before transportation to hospitals did not seem to be associated with improved outcomes in such circumstances [34]. The benefits of transporting and caring for spontaneously breathing rather than intubated and ventilated patients with large burns is obvious both from a timeliness and efficiency and from a resource management perspective in an overwhelming mass casualty situation. In addition, lowering the aim for fluid resuscitation and thus limiting the fluid's pull for more fluid has been proven useful to limit mortality [13]. In an austere situation with no dependable access to either monitoring or qualified airway management, it is sensible and may prove lifesaving to avoid any "fluid creep". Moreover, whilst airway control and high-rate resuscitation are not highly challenging in a single patient care in well-resourced countries, the situation changes dramatically when multiple patients need simultaneous attention and care.

The TWBG formula also proposes a flat fluid rate for 24 h. If recommendation #8b to regularly adjust fluid rates to patients' status is overlooked or delayed due to resource scarcity, this 24 h flat rate seems in opposition to current understanding of the pathophysiology of burn shock, which emphasizes the highest need of fluid resuscitation in the first hours [45]. This reason underlies the usual recommendations to give half predicted fluids in the first 8 h post burn [1–3,28], or even to give an initial fluid bolus [6]. A retrospective study even associated fluid resuscitation started earlier than 2 h with better clinical outcomes in children with burns larger than 50 %TBSA [47]. However, in mass burn casualty situations, consensus expert opinion of the TWBG was that implementing a straightforward strategy, reducing the risk of edema-related complications, and making initial evacuations faster and smoother through a simplified on-scene and en-route care should outweigh the potential drawbacks of delaying initial proactive fluid resuscitation. This delay should also be partly compensated for by providing oral hydration *ad libitum*, preferably with ORS, as early as possible until due fluid resuscitation is feasible.

The TWGB recognizes that its recommendation might appear as a paradigm shift, yet the simplicity of the formula and its calculation, identical for both oral and intravenous fluids, may significantly decrease confusion in the prehospital environment and in non-specialized "first receiving hospitals" for which it was intended. The simplified formula should simplify the teaching and implementation of fluid resuscitation for burns for a wide range of healthcare staff.

On the whole, the main strength of the TWGB simplified resuscitation formula is its ease of use, which should help achieve a better outcome in the largest number of patients despite being potentially suboptimal in some. It also provides an easy calculation tool to design emergency fluid stocks and to scale an initial surge in the framework of burn disaster preparedness, with little dependency on TBSA scenarios, since only the proportion of patients with burns below or above 40% TBSA sizes the quantity of intravenous fluids *vs* ORS.

These recommendations are not substitute to current resuscitation guidelines, nor do they wish to overall challenge these in everyday practice for individual burn patients. Contrarily, TWGB recommendations are proposed as an add-on for a very specific situation in the early, overwhelmed initial care and distribution phase of a mass burn casualty incident. Current resuscitation guidelines should still be used as soon as specialized burn care and resources are available.

5. Conclusion

In a mass burn casualty disaster, when resources are scarce, the simplified initial fluid resuscitation formula of 100 mL/kg/24 h as proposed by the TWGB should be appropriate for most salvageable patients, although special attention should be paid to basal resuscitation fluid estimates in young children. The simplified formula should help ensure the best probability of survival for the largest number and potentially help reduce complications from fluid creep. The formula provides a mere starting point and should be converted to a tailored approach as soon as practicable. The recommended formula's simplicity to teach, learn and implement will help caregivers comply with recommendations and improve overall delivery of resuscitation until specialist burn care is available. This will hopefully result in improved overall survival in the specific situation of mass burn casualty disasters.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.burns.2021.02.022.

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