-PLUS Prehospital Mass-Casualty Triage: A Strategy for Addressing Unusual Injury Mechanisms

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Abbreviations:
EMS = emergency medical services
MOI = mechanism of injury
START = Simple Triage and Rapid Treatment

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Abstract

Introduction: Simple Triage and Rapid Treatment (START) and more recently developed prehospital casualty triage algorithms are widely used, in part because they are easy to teach and learn, and can be performed rapidly. Every rapid triage protocol has inherent, significant limitations: (1) no mechanism of injury (MOI) considerations; (2) limited assessment points; and (3) no refinement in truly mass-casualty situations where transport of "minor" or "moderate" patients may be delayed.

Hypothesis: When rapid initial triage protocols are utilized, a significant triage deficiency ("under-triage") may occur when "minor" or "moderate" casualties actually are more severely injured than initially triaged. Some MOI produce casualties with subtle or latent (i.e., hidden or delayed) signs and symptoms not considered in the commonly used prehospital triage algorithms. This research did not focus on START or other initial triage screening methods. Instead, it focuses on developing follow-on triage guidance to more specifically prioritize "delayed transport" casualties based upon signs and symptoms related to their MOI.

Methods: Using expert opinion and accepted clinical criteria, triage algorithms were developed to re-evaluate patients triaged to "minor" and "moderate" cohorts. A detailed literature search produced a draft list of relevant signs and symptoms for each selected MOI. The lists then were evaluated by a multi-disciplinary panel of experts via an anonymous, mail-based Delphi method. The input shaped triage algorithms for each selected MOI, which then were subjected to a second stage Delphi process.

Results: Consensus was achieved using the Delphi method. The algorithms extend patient assessment beyond the rapid initial triage protocols and incorporate triage criteria specific to each selected injury mechanism or condition: (1) penetrating injuries; (2) unconventional MOI (burns, blast, chemical, radiation); (3) smoke and other inhalation exposure; and (4) injuries with concomitant pregnancy. The full list of triage protocols is designated by the acronym "-PLUS".

Conclusions: "-PLUS" Prehospital Casualty Triage may supplement the strengths of already existing, widely accepted mass-casualty triage strategies. It does not displace START or other rapid initial triage protocols, but in mass-casualty situations with extensive delays in transport, it provides a method to identify under-triage of seriously injured casualties. "-PLUS" also presents a framework for capturing the triage considerations used by experienced medical providers, and so may provide a valuable teaching tool for training future triage professionals. Further research and field assessment is required.

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Introduction

Triage is a process that matches medical needs with available resources according to a priority scheme designed to achieve a defined goal. Prehospital triage of mass casualties assesses the patients' medical conditions (needs) and assigns a priority (resource-matching) for whom is transported first (one resource) to an appropriate medical receiving facility (another resource) to achieve the best possible patient outcomes (goal for prehospital patient triage). Domres *et al* define disaster triage of casualties as "the selection and categorization of the victims of a disaster with the view to appropriate treatment according to the degree of severity of illness or injury and the availability of medical and transport facilities".[1] More simply, the goal of casualty triage during disasters has been presented as "do the greatest good for the greatest number".[2,3]

Prehospital emergency medical services (EMS) personnel often are taught one specific disaster triage algorithm that is easy to teach, learn, and retain by EMS providers who rarely practice it. The most widely used triage algorithm is Simple Triage and Rapid Treatment (START),[1] developed in Newport Beach, California in 1983 by the Hoag Hospital and the Newport Beach Fire Department.[4] In a survey of state EMS agencies, START is used by 71.4% of the states that participated in the survey.[5] One study reported "that at the first test of this system (START), field personnel triaged mock patients with 93% accuracy after two hours of training," although "accuracy" is not defined.[6]

While START is easy to learn, teach, and retain, it may "under-triage" casualties from injury mechanisms other than blunt trauma. With an extension of the triage process beyond the basic START approach, casualties triaged to a delayed transport category may receive a more appropriate triage designation.

The START protocol is designed around three assessment components: (1) respirations; (2) pulse; and (3) mental status, and is based upon the human body's physiological reaction to blunt trauma. In the START system, patients are categorized into four categories: (1) Red; (2) Yellow; (3) Green; (4) and Black.[7] The "Red" category is for patients who are critically injured and require immediate transport. "Yellow" patients are injured and require care; however, they can survive for a short period of time without intervention. "Green" patients often are categorized as the "walking wounded". These patients will likely survive without medical intervention and often are capable of caring for themselves. Lastly, "Black-tagged" patients, also known as "Expectant" patients, are deceased or have such catastrophic injuries that they are not expected to survive to be transported".[7] It is important to note that, in the START algorithm, only patients who are not breathing or pulseless are black-tagged. The order of priority for patient transport is Red, Yellow, Green, and finally, any survivors in the Black-tagged category.

Recently, several other rapid triage algorithms have been proposed in the peer-reviewed literature by medical professionals as evolutions beyond START (Table 1). These publications post-dated the onset of this research project. In this article, all of these protocols are grouped as "rapid initial triage protocols". The strength of these rapid initial triage protocols is that they are easy to learn, teach, and retain and they can be performed rapidly under field conditions. However, they may dangerously "under-triage" casualties, especially those with mechanisms of injury (MOI) other than blunt trauma. The MOI is the means by which energy interacts with the human body to create injury.[12] It impacts the human tissue in the form of mechanical, thermal, chemical, electrical, or radiation energy.[13] Any large amount of energy applied to the body in any of these forms can create significant injury. By understanding each major MOI and its related life-threatening injuries, the emergency care provider can more specifically assess the casualty for injury, rather than relying on only the superficial criteria in the START or other initial triage processes. Creel pointed out that "Five to 15 percent of those patients, despite normal vital signs and no apparent anatomic injury on the first survey, will later exhibit severe injuries that are discovered on repeat examinations".[13] If the emergency care provider can identify the MOI, the injuries to the casualty may be better assessed prior to clinical deterioration.[13,14] The "MOI is also an important triage tool and is information that must always be reported to the emergency physician or trauma surgeon".[13]

Dangerous triage inaccuracy, "under-triage", occurs when "green-tagged" or "yellow-tagged" casualties actually may have more urgent injury than initially identified using rapid initial triage criteria. Some MOIs will produce casualties with subtle, latent (i.e., hidden or delayed), or unusual presenting symptoms and signs that START does not consider in assigning treatment and transport priorities. Symptoms and signs that are predictive of potentially urgent injury well before the concerning START criteria are encountered include:

1. Casualties suffering penetrating wounds to the head, neck, chest, or abdomen with initially stable vital signs;
2. Unconventional casualties with blast injuries, burns, chemical exposure, and radiation injuries with cutaneous changes indicating severe exposure;
3. Smoke and other inhalation casualties with subjective shortness of breath and soot in their nasal passage, but otherwise may initially appear well. They even may have a respiratory rate within the normal (i.e., delay category) range, prior to sudden deterioration from airway compromise; and
4. Pregnant casualties, due to their significant physiological changes from late pregnancy, may obscure signs and symptoms of trauma, and rapid initial triage protocols do not consider the fetus in determining priority transports.

Multiple reports reflect concern about the limitations of START when applied as the only triage modality for casualty scenarios beyond blunt trauma: "Many minor trauma patients are generated and due to external bleeding can be difficult to differentiate visually from more major injuries";[15] "The START and JumpSTART systems are often used to triage victim of mass casualty incidents. However, these systems were not designed for use in chemical incidents and may consequently lead to mis-triage, especially for agents with delayed symptoms onset, such as

MASS Triage	SALT Triage
- "Move, Assess, Sort, and Send"[8] - Trademarked by National Disaster Life Support Foundation[9] - Four categories: Immediate, Delayed, Minimal, and Expectant - Allows civilian and military personnel to operate similarly during a disaster[5] - Weaknesses include no tagging system, ineffective use of the system if casualties are spread across a large area, and reprioritization based upon the number of casualties—not their severity[5]	- "Sort, assess, lifesaving interventions, and treatment and/or transport[10] - A proposed guideline derived through consensus opinion and a review of current triage systems[11] - "Intended to be used for all-hazards events and be applicable in both adults and children"[10] - Four steps when triaging include initial triage of casualties using voice commands, initial rapid treatments, assessment of each casualty and prioritzation, and the initiation of treatment and transportation[10]

Table 1—Characteristics the MASS and SALT systems

mustard";[16] ("JumpSTART" was published in 1995 for pediatric triage and parallels the structure of the START system[17]). "START and other basic triage systems used by EMS may be insensitive to critical but initially subtle injuries from explosives (small shrapnel, smoke and heat inhalation and blast injuries)";[15] Initial signs and symptoms of blast injury "may be subtle and underestimated," but patients can decompensate quickly.[18]

The more recently proposed rapid initial triage protocols have not yet been evaluated for under-triage, but similar problems may be anticipated. In addressing this important issue, it is useful to retain the positive aspects of the rapid initial triage protocols (simple, easy to teach, reproducible, and rapidly performed). The major issue to address in a true mass-casualty incident, however, is a follow-on triage method for patients who, because of initial triage and the large number of casualties, may be subject to a prolonged delay in transport. Ideally, this requires MOI-based guidance for use by experienced medical providers to identify patients in the "moderate" or "minor" cohorts who should be up-triaged. A rapid, but systematic evaluation is desirable, similar to the primary survey in Basic or Advance Trauma Life Support.[19,20] The strategy proposed in this paper, therefore, establishes a research-based, follow-on, triage process for patients not designated as immediate (Red) or Expectant (Black) under the rapid initial triage protocols. The sequential nature of this approach is reflected in its addendum-styled title, "-PLUS"—a second, follow-on, triage process distinct from any rapid initial triage protocol, and is applied when time permits, for patient cohorts in the casualty collection area designated as delayed (Yellow) or minor (Green).

Methods

The research design was approved by the George Washington University's Office of Human Research prior to conducting the investigation. The authors selected the Mechanisms of Injury (MOI) in the study. Detailed research of the published medical literature was conducted by the lead author to identify the injury profile for each MOI. Symptoms and signs predictive of increased injury severity were identified. Subtle and latent (or hidden) symptoms and signs, with their earliest apparent manifestations, were particularly sought. These predictive symptoms and signs were compiled into a draft algorithm for each specific MOI category. Blunt trauma was not selected for this initial study, since START, the original rapid triage protocol, seemed to focus primarily upon this MOI.

An expert panel of six prehospital casualty care experts was selected through convenience sampling and the following specific selection criteria:

1. Professional experience (minimum of 10 years) as a paramedic, emergency physician, or other physician with experience in prehospital medical care;
2. Experience treating casualties in a multiple- or mass-casualty incident;
3. Professional familiarity with the START Prehospital Casualty Triage Process; and
4. Willingness to participate in the study.

The expert cohort included a board certified emergency physician and EMS medical director, a board certified emergency physician with extensive disaster response and emergency medical services experience, a military physician, two practicing full-time paramedics with 10 years or more of field experience including multiple-casualty incidents and mass-casualty disasters, and one full-time, college faculty member and director of an accredited paramedic education program with more than 10 years as a paramedic.

Informed consent was obtained according to the George Washington University Office of Human Research guidelines. Information regarding the experts' professional experience and familiarity with triage then was gathered. This included questions regarding years of experience in emergency medicine or prehospital care, familiarity with START triage, and experience in actual disasters. The algorithms were evaluated via expert clinical judgment using an anonymous, mail-based Delphi method. To prevent group bias or influence among the physician and paramedic cadre, the expert judgment was conducted via postal mailings with comment authorship blinded from panel members. To sustain this anonymity, experts only were identified by a letter (i.e., Expert A, Expert B, etc.). Names, phone numbers, and other identifying information were not used.

To promote consistency, each expert was provided a copy of the START Prehospital Casualty Triage System developed by the Hoag Hospital and the Newport Beach Fire Department (Newport Beach, CA).[4] They were provided with a random, unranked list of the aggregate signs and symptoms for each MOI category and asked to indicate their criteria to "up-triage" casualties that would other-

Mechanism of Injury*	Suggested Criteria**
Penetrating Trauma	Penetrating injuries to the head, neck, chest, abdomen, or pelvis Penetrating injuries from suspected high-velocity projectiles
Labor/Pregnant Casualties	Pregnant casualties with injuries Casualties in active labor
Unconventional Casualties	Blast Injuries Burn Injuries Radiation Injuries Cutaneous Chemical Exposure Injuries
Smoke and other inhalations	Smoke Inhalation Other Chemical Inhalations

Table 2—Description of -PLUS triage categories
*"Mechanism of Injury" is a description that depicts "the strength, direction, and nature of forces that cause injury to a patient".[8]
**Suggested Criteria: criteria identified from the literature and research sources that identified the extent and significance of a casualty's injury.

Mechanism of Injury*	Suggested Criteria**	Number of Experts Supporting***
Penetrating trauma	Penetrating to the head Penetrating to the neck Penetrating to the chest Penetration to the abdomen	6/6
	Penetrating to the pelvis	4/6
	Pain at the injury site	1/6
	Minor nicks or scratches possibly caused by high-velocity fragments Uncontrolled bleeding Any penetrating wound to an extremity without an exit wound	0/6
Labor/Pregnant Casualties	Any trauma to abdomen Any consistent contractions Abdominal pain or contractions	4/6
	Any vaginal bleeding	3/6
	Mere existence of pregnancy Any casualty in second or third trimester of pregnancy	2/6

Table 3—Expert supported triage upgrade criteria for penetrating injuries and labor/pregnant casualties
*"Mechanism of Injury" is a description that depicts "the strength, direction, and nature of forces that cause injury to a patient".[8]
**Suggested Criteria: criteria identified from the literature and research sources that identified the extent and significance of a casualty's injury. This also included suggestions from the experts.
***Number of Experts Supporting: the number of the experts supporting the proposed triage criteria to upgrade a casualty from minor or moderate to immediate during the second Delphi stage.

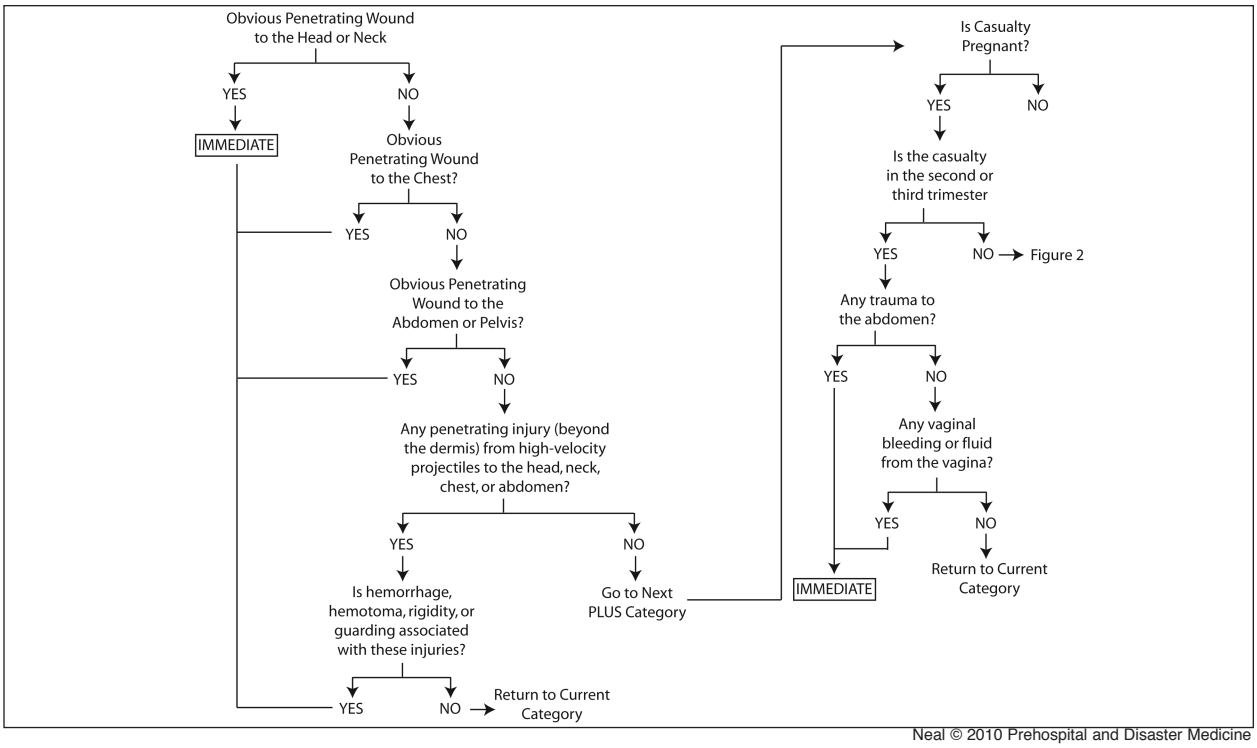

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Figure 1—Algorithm for upgrading the priority of penetrating injuries and labor/pregnant casualties

wise be subject to delayed transport from the scene (i.e., "moderate" casualty [yellow tag] or "minor" casualty (green tag) that should be upgraded to immediate [red tag]). The experts also could provide comments and additional criteria for each identified subtle symptom and sign that indicate increased injury severity.

The Modified Delphi Technique was conducted in two stages. The first round of feedback provided the opportunity for experts to agree or disagree with the selected criteria, rank their importance, provide comments, and submit additional criteria. Using the information obtained from expert judgment and the literature, a triage algorithm was developed in a flow diagram format for each MOI. The aggregate feedback from the first stage was mailed to each expert, formatted as tables of suggested criteria, and indicating the number of experts from the panel that supported each particular triage element. The experts also were provided with the draft triage algorithms for each MOI category. This second Delphi stage permitted the experts to agree, disagree, or clarify their support for the "upgrade criteria" while weighing the opinions of the other experts. The lead author processed feedback and the algorithms were finalized.

Results

The following MOI and medical conditions were investigated: (1) penetrating injury; (2) unconventional mechanisms (blast, chemical, radiation and others); (3) smoke and other inhalation injuries; and (4) trauma with concomitant pregnancy. The list is organized using the acronym "-PLUS" (Table 2).

Table 3 summarizes the triage criteria supported by the experts for victims with penetrating injuries and for labor/pregnant casualties. Every expert agreed that a "penetrating wound to the head, neck, chest, or abdomen" was grounds for higher priority transport. Four of the experts identified a "penetrating wound to the pelvis" as an important criterion. In the labor/pregnancy category, four experts agreed that "any consistent contractions", "any trauma to abdomen", and "abdominal pain or contractions" were grounds for higher priority transport. Three experts agreed that "any vaginal bleeding" was an acceptable criterion. The suggested algorithm for upgrading the priority of penetrating injuries and labor/pregnant casualties is in Figure 1. "Beyond the level of the dermis" was added as a criterion for the penetrating injuries algorithm. In the second Delphi stage, experts did not suggest any additional criteria or changes to the presented labor/pregnancy triage algorithm.

The panel's consensus list of upgrade criteria for each mechanism in the unconventional category of MOI is provided in Table 4. In the blast category, six experts selected "proximity to the blast" and "shortness of breath" as upgrade criteria. Five experts selected "coughing up blood or blood-tinged sputum," whereas four experts selected "chest pain." Figure 2 is the resultant algorithm for upgrading the priority of unconventional (blast injuries, burn injuries, radiation injuries, and cutaneous chemical injuries) casualties. Two changes were suggested to the blast portion of the unconventional algorithm of -PLUS.

The criteria to upgrade a burn casualty largely were consistent with the recommendations of the American Burn Association for a significant burn injury (Table 4). Five of the six experts identified "any burn to a critical area (hands, feet, genitalia, or face)", "any history of being burned in a confined space", "any electrical burn", and "any burn associated with other major trauma" as upgrade criteria. "Any circumferential burn", "any third degree burn greater than 10%", and "second-degree burn of greater than 25% of body

Mechanism of Injury*	Suggested Criteria**	Number of Experts Supporting***
Blast Injury	Shortness of the breath Proximity to blast	6/6
	Coughing up blood or blood-tinged sputum	5/6
	Chest pain	4/6
	Coughing Abdominal pain Bleeding from ears or nose Any walking wounded who were indoors during a blast which occurred inside the same structure	3/6
	Inability to hear Any confusion Nausea/Vomiting The "lucky survivor" or the person still alive who is surrounded by dead victims	2/6
	Tinnitus	0/6
Burn Patients	Any burn to a critical area (hands, feet, genitalia, or face) Any history of being burned in a confined space Any burn associated with other major trauma Any electrical burn	5/6
	Any circumferential burn Second-degree burn of greater than 25% of body surface area Any third degree burn greater than 10%	4/6
	Severe pain	1/6

Table 4—Expert supported triage upgrade criteria for unconventional casualties
*"Mechanism of Injury" is a description that depicts "the strength, direction, and nature of forces that cause injury to a patient."[8]
**Suggested Criteria: criteria identified from the literature and research sources that identified the extent and significance of a casualty's injury. This also included suggestions from the experts.
***Number of Experts Supporting: the number of the experts supporting the proposed triage criteria to upgrade a casualty from minor or moderate to immediate during the second Delphi stage.

surface area" were identified by four of the six experts. The burn portion of Figure 2 shows the suggested algorithm for the upgrading triage. The algorithm was adjusted to focus on the injury depth and the location of the burns.

In the radiation exposure category, three of six experts identified four criteria to upgrade a casualty: (1) "vomiting"; (2) "bloody diarrhea"; (3) "hypotension"; and (4) "any CNS dysfunction" (Table 4). When examining the suggested triage algorithm (Figure 2), one expert pointed out accurate dosage criteria would be difficult to measure in the field. To keep the algorithm manageable, dosage criteria largely were substituted by clinical criteria (nausea, vomiting, bloody diarrhea). "Erythema consistent with a burn" also was added as criteria to upgrade the priority of a radiation injury.

In the chemical exposure category, five experts chose "rales (pulmonary edema)" as an important sign to upgrade these casualties (Table 3). Four experts selected "erythema of the skin (25% or greater)" or "burning of the throat and nose". The cutaneous chemical exposure portion of Figure 2 shows the suggested upgrade algorithm.

The expert supported priority upgrade criteria for triage of smoke and other inhalation injuries are provided in Table 5. For smoke inhalation, all experts supported three upgrade criteria: (1) "burns to face or nose hairs"; (2) "wheezing lung sounds"; and (3) "difficulty speaking". One-half of the experts supported "hoarseness" and "suffered exposure to fire in a confined area (i.e., house fire)." Half of the experts supported "sore throat", "soot around mouth and nose", and "swollen lips". For other inhalation injuries, the criteria were similar to smoke inhalation (Table 5). Five experts supported "difficulty breathing", "rales or crackles", and "stridor" as criteria. Four experts selected "Uncontrollable

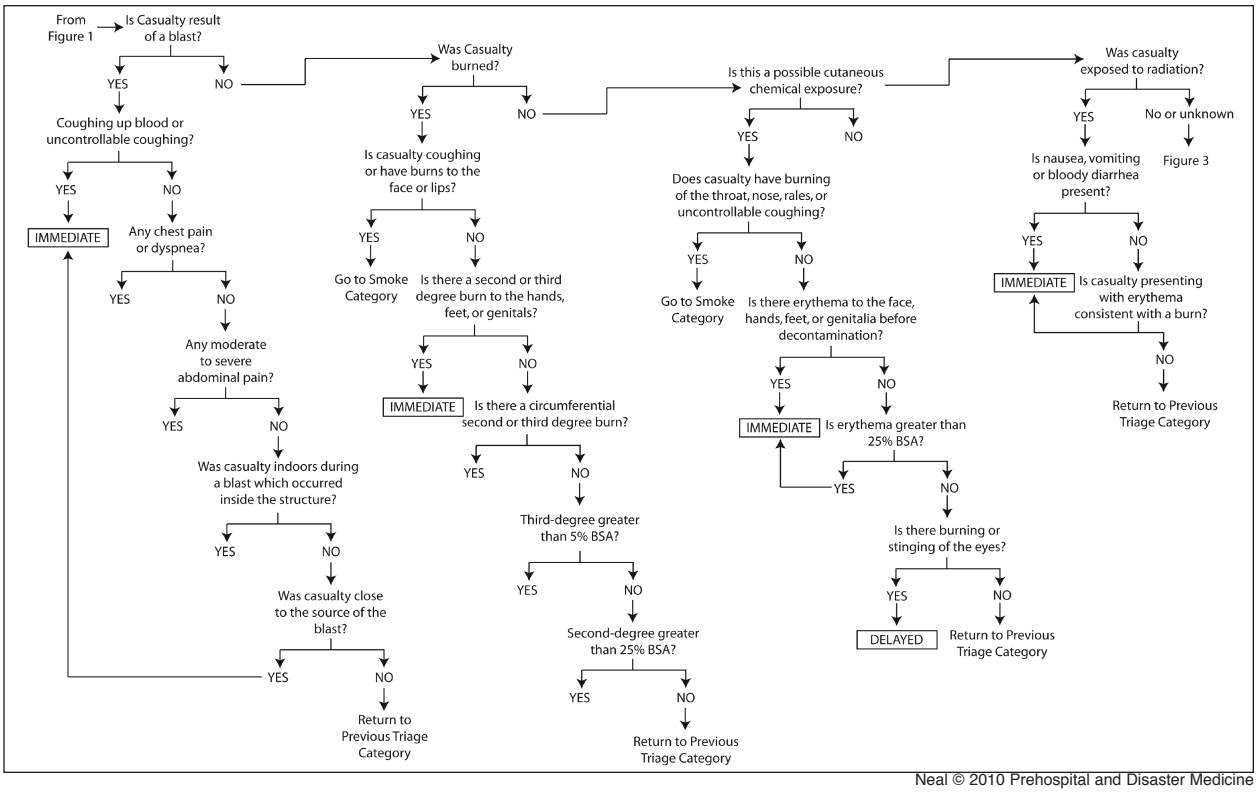

Figure 2—Algorithm for upgrading the priority of unconventional (blast, burn, radiation, and cutaneous chemical injuries) casualties

Mechanism of Injury*	Suggested Criteria**	Number of Experts Supporting***
Radiation Exposure	Bloody diarrhea Vomiting Hypotension Any CNS dysfunction	3/6
	Whole body radiation of at least 25 rem (0.25 Sv)	2/6
	Nausea Exposure of local skin to radiation of at least 600 rem (6 Sv) Exposure of 15 rem to the eyes Any exposure of 3.5 Gy Absorbed dose of at least 75 rem (7.5 Sv) to tissues other than the skin Any erythema	1/6
Cutaneous Chemical Exposure	Rales (pulmonary edema)	5/6
	Erythema of the skin (25% or greater) Burning of the throat or nose	4/6
	Uncontrollable coughing Known history of exposure to a vesicant	3/6
	Burning and stinging of the eyes	2/6
	Rhinorrhea	1/6

Table 5—Expert supported triage upgrade criteria for unconventional casualties (continued)
*"Mechanism of Injury" is a description that depicts "the strength, direction, and nature of forces that cause injury to a patient".[8]
**Suggested Criteria: criteria identified from the literature and research sources that identified the extent and significance of a casualty's injury. This also included suggestions from the experts.
***Number of Experts Supporting: the number of the experts supporting the proposed triage criteria to upgrade a casualty from minor or moderate to immediate during the second Delphi stage.

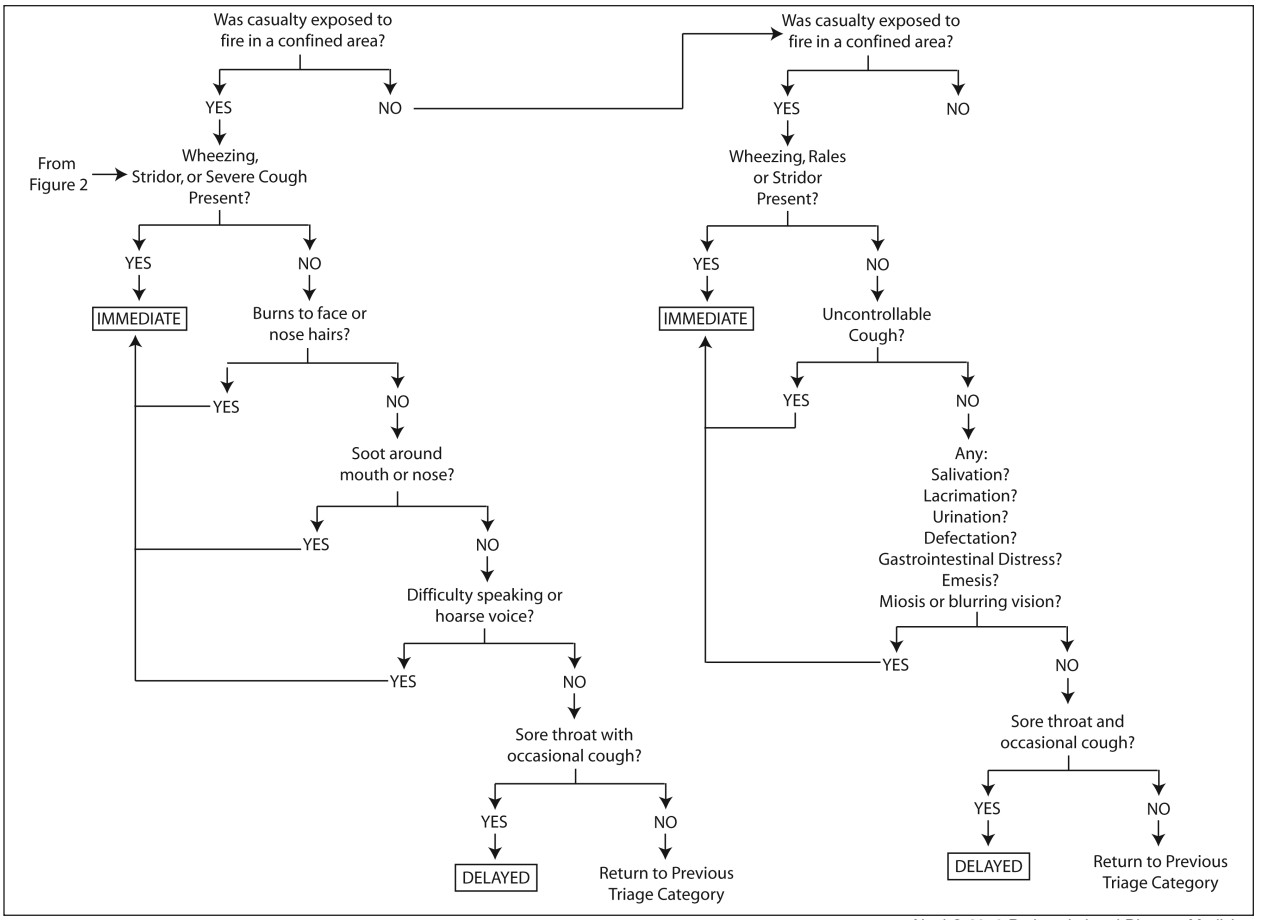

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Figure 3—Algorithm for upgrading the priority of smoke inhalation or other inhaled chemical inhalation casualties

bowels or bladder "and" salivation or drooling. Three experts supported "miosis or blurry vision", "lacrimation", and "emesis or nausea". Experts did not add any additional criteria or suggest any changes to the smoke inhalation or other inhaled chemical inhalation triage algorithm (Figure 3).

At the completion of the Modified Delphi Method, the suggested triage algorithms were compiled into one organized algorithm. This is the suggested triage algorithm for the "-PLUS" Prehospital Casualty Triage System.

Discussion

The use of -PLUS guides the triage officers through sequential steps, based upon the relevant mechanisms of injury (MOI) and/or pregnancy status that assess delayed-transport casualties. Although -PLUS adds complexity, it is based upon widely recognized clinical decision criteria within the medical profession that are used during emergency department trauma care. It is expected that this algorithm is conducted only by senior/experienced field providers, using printed flow diagrams as decision-support tools, and only in mass-casualty situations with significant delays in patient transports. In these settings, it may more appropriately identify all patients that would most benefit by field treatment and high priority transportation to hospital care. The time and effort for this methodology is projected to be equivalent to that of the primary survey in Basic and Advanced Trauma Life Support, but this issue must be studied further under field conditions.

The -PLUS does not dismiss START, MASS, SALT or other rapid initial triage protocols, but does address their shortcomings during mass-casualty incidents. Owens identified the lack of a secondary triage method as a weakness of the START system.[5] -PLUS also addresses another limitation of any rapid triage approach. As described by Hogan and Lairet for START, the "lack of differentiation between types of trauma" can be problematic.[8] The use of the -PLUS guides the triage officer to the relevant MOI and then, prompts considerations of the MOI-specific criteria in re-assessing the patient.

The expert panel's additional comments cited the difficulty of creating detailed (yet practical) triage criteria. This was apparent when discussing more detailed criteria for burns casualties, radiation casualties, and smoke inhalation casualties. When considering burn casualty triage, the experts' comments reflected the difficulty of calculating detailed burn percentages. In the suggested -PLUS Prehospital Casualty Triage Algorithm, some burn percentage criteria were retained, as -PLUS is meant to be conducted by experienced medical providers. A similar issue was identified when considering radiation dosage criteria to determine triage upgrade for radiation casualties. Although exposure of local skin to radiation of at least 600 rem (6 Sv)

or any exposure of 3.5 Gy clearly require more advanced treatment, these doses are difficult to calculate without a dosimeter. Furthermore, triage must be conducted quickly and without equipment, thus dictating the use of clinical symptoms such as nausea and vomiting rather than radiation dose.

At the other extreme, panel experts identified some MOI that necessitate simple, almost obvious triage criteria. When examining penetrating injuries, for example, one expert noted that "it is the closest [MOI] to being what it looks like." The algorithm presents clear criteria to upgrade a casualty with a penetrating injury. Smoke inhalation and blast injuries also have simple MOI criteria to indicate the need to upgrade a casualty's priority for treatment and transport. Exposure to fire in a confined space and exposure to a blast indoors are straightforward criteria to upgrade a casualty with smoke inhalation or blast exposure, respectively. Although simple, these criteria are identified in research and widely supported by experts as clear predictors of the serious injury in certain MOIs.[21,22]

Multiple experts commented that patterns of symptoms and signs, rather than the individual, proposed criteria, are important in conducting triage and making decisions. Experts stated that they "expect these (signs and symptoms) together or in groups, not in isolation, to be significant" or "would look for abnormal patterns of vitals signs." The authors agree with this important observation, and it is consistent with how experienced prehospital and in-hospital medical professionals conduct patient assessments: they commonly analyze groups of findings as they perform the history and physical examination.[23,24]

Since the presentation of triage upgrade criteria grouped in tables or lists are not operationally useful, the triage algorithm was developed. A limitation of the algorithm, however, is the sequential presentation of assessment criteria. The sequential consideration of -PLUS findings, however, is not required. Instead, the decision points in the algorithm can be used as guidelines to upgrade casualties. Grouped findings, however, may be discussed in any training program as important for strengthening the triage officer's determination as to the appropriate assignment for transport and treatment priority.

The -PLUS is based upon widely accepted clinical information developed using experts and a detailed literature review. For example, paramedic basic training emphasizes the latent presentation of shock in penetrating wounds and respiratory collapse from smoke inhalation. Many of the burn criteria are derived from accepted criteria for critical burns.

It is important to emphasize that the final algorithms established through this research are based upon expert opinions. Future field study of the-PLUS algorithm is needed. In particular, a prospective study of -PLUS, perhaps as a shadow to or parallel with usual EMS field evaluations of traumatic injuries, would be invaluable in assessing the validity of the algorithms. In a search of MEDLINE®, only two prospective studies evaluating START and JumpSTART with actual casualties could be identified. These studies focused on the efficacy of START and the performance of multiple triage tools, respectively.[25,26] The paucity of evidence-based research to support long-accepted START and JumpSTART tools exacerbates the concern for any follow-on tool based on initial START or JumpSTART triage decisions. Reports assessing the newer rapid triage protocols have not yet been published.[20,27] While difficult to conduct, ethical, objective field study processes should be developed for current and proposed prehospital triage tools.

Two additional studies of the -PLUS criteria are underway. One is a retrospective study seeking to evaluate the -PLUS algorithm using cases with relevant MOI from a large trauma registry database. In this research, the START and -PLUS criteria are applied sequentially (by a blinded expert similar to those in the initial study) to casualty presentations from prehospital patient care reports, case studies, and historical accounts to determine if the -PLUS criteria upgrades the casualties appropriately, based upon their final hospital diagnosis. An additional study is underway to evaluate the sensitivity, specificity, and reproducibility of the -PLUS criteria. This is being conducted using a small number of experienced paramedics who triage actual case presentations in a written exercise following a short -PLUS training program.

Although the criteria are based upon fundamentals of paramedic training, -PLUS was designed to be conducted by an experienced paramedic or physician. The process of sorting through the minor and moderate casualties requires an ability to rapidly discern multiple, relatively subtle findings that become important as a group or in relation to a known MOI. An experienced paramedic has likely developed clinical decision-making skills for this role. The shortage of experienced providers on an incident site may make the use of -PLUS more difficult. But, since this is a follow-on triage of casualties after sorting via a rapid triage protocol, appropriate personnel can be assigned to the moderate and minor casualty collection areas as more senior paramedic or physician personnel arrive to the incident scene. Since this activity occurs in a casualty collection site (in contrast with START, MASS, and SALT, which are conducted where the casualty first is encountered), a relatively smaller number of experienced providers is needed to effectively apply the -PLUS triage to the casualty pool designated as minor or moderate.

Conclusions

The -PLUS Prehospital Casualty Triage System may expand upon the strengths of an existing and widely accepted, rapid, initial triage strategies. It provides guidance for an experienced clinician to re-triage minor and moderate casualties, identifying and considering subtle symptoms and signs predictive of critical injury specific to the relevant MOI. Thus, casualties suffering from penetrating injuries, unconventional MOIs, smoke (and other inhalation) injuries, and injured pregnant casualties can be more accurately evaluated and possibly retriaged to immediate transport and treatment if indicated. This expanded triage strategy maintains the efficiencies of rapid, initial triage protocols, but potentially minimizes dangerous under-triage of seriously injured casualties subjected to prolonged transport times. Future research should examine the sensitivity and specificity of the -PLUS criteria in the field setting under actual or simulated conditions.

The "-PLUS" also presents a framework for capturing the triage considerations used by experienced medical providers, and so may provide a valuable teaching tool for training other healthcare professionals who will be caring for trauma patients. Early indications suggest that prehospital instructors are receptive to using this tool for instructional purposes, and further study of this potential role should be considered.

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