Mass casualty triage in the chemical, biological, radiological, or nuclear environment

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Field trauma triage systems currently used by emergency responders at mass casualty incidents and disasters do not adequately account for the possibility of contamination of patients with chemical, biological, radiological, or nuclear material. Following a discussion of background issues regarding mass casualty triage schemes, this paper proposes chemical, biological, radiological, or nuclear-compatible trauma triage algorithms, based on a review of the literature and the input of recognized content experts. A basic trauma triage template is first proposed, with patient assessment limited to ability to walk, presence of breathing, and ability to follow commands. This template is then modified for use in chemical, biological, and radiation/nuclear situations in which the exposed or contaminated victims have also sustained conventional trauma. The proposed algorithms will need further refinement and testing. *European Journal of Emergency Medicine* **12:287–302 © 2005 Lippincott Williams & Wilkins.**

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Introduction

Field trauma triage systems currently used by emergency responders at mass casualty incidents and disasters (however those are defined – see Appendix 1) do not adequately account for the possibility of contamination of patients with chemical, biological, radiological, and/or nuclear (CBRN) material. A system is needed that can help the healthcare personnel who are performing triage assess whether there has been exposure to or involvement of CBRN agents (detection), protect themselves from secondary contamination, account for the clinical implications of the contamination in the triage algorithm, and still provide accurate, rapid, and reproducible triage of large numbers of patients using minimal resources.

The objective of this paper is to propose CBRN-compatible trauma triage algorithms, based on a review of the literature and the input of recognized content experts. It is pre-supposed that this system will be applied to a disaster with a discrete scene (e.g. a building collapse due to a bombing with a large radiation dispersal device) or multiple discrete scenes (e.g. several simultaneous chemical weapons releases in a city), and not to an event with widely dispersed patients and no scene (e.g. multiple smallpox patients scattered around Europe and North America after aerosol dispersal at an airport). The primary focus shall be on triage of physically injured patients, with less emphasis on those whose sole source of injury is the CBRN agent, although it is recognized that work is needed in the latter area. Modifications may be needed to adapt these triage algorithms to non-trauma situations, such as the 1995 Tokyo sarin attack. The paper will also concentrate primarily on the actual triage of victims, and less so on detection and provision of protection from contamination.

While the CBRN acronym is often considered to best apply to intentional attacks, this paper will make no distinction based on etiology. The proposed algorithms are designed to be applicable to both intentional and unintentional events. While it can be argued that there are differences in scene safety considerations (such as the possibility of a secondary device or other direct assault on responders) between intentional and unintentional events, responders may not always have information allowing them to form a reasonable judgment regarding threats as they respond, and it seems prudent to exercise significant caution in any disaster response. While some may also argue that different types of CBRN agents are seen in intentional as opposed to unintentional releases, these differences may not be as great as would appear [1]. For example, in the case of chemical agents, it has been stated that '…the main difference between industrial disasters and those of chemical sabotage, warfare, and terrorism may be a distinction only of malicious intent' [2]. It may also not be known in the early stages of the response whether the event was intentional.

Types of triage systems

In a 1986 paper, the Committee on Trauma of the American College of Surgeons (ACS-COT) noted three types of trauma triage: field triage, inter-hospital triage,

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and mass casualty triage [3]. It was indicated that field triage 'involves an estimation of injury severity at the scene of the accident and the subsequent matching of patient needs with available resources'. While not defining inter-hospital triage, a set of criteria for such triage was presented, focusing on trauma patients who were initially transported to a non-trauma center, but required a trauma center's advanced or specialized services. Mass casualty triage was not defined or discussed at all. Despite the focus of the ACS-COT paper on field triage, the terms set forth seem reasonable, and will be used here. (See Appendix 1 for terminology notes.)

Currently, there are many trauma triage schemes in use throughout the world. Few of these, however, are intended for mass casualty triage in the sorting and prioritizing of multiple patients at a mass casualty incident or disaster. Instead, most are for field triage, intended to allow prehospital personnel to determine whether a single given patient requires the resources of a trauma center. The first such field triage system was likely the Triage Index, initially described in 1980 by Champion and colleagues [4], and built on recognition that 'the most consequential [triage] judgments are often made at the time of injury by non-physician personnel' in deciding to what facility to transport the injured patient. Minor revisions to this system resulted in the development of the Trauma Score a few years later [5]. While this system was intended initially for prognostic use in the hospital, the same group of researchers in 1985 proposed the use of the Trauma Score in the prehospital setting, and prospectively studied the inter-rater reliability of field personnel in scoring patients using the Trauma Score [6].

Champion and colleagues [7] presented a revision of the Trauma Score in 1989, the Triage Revision of the Trauma Score, usually simply referred to as the Revised Trauma Score (RTS). Other field triage systems include the Trauma Triage Rule (TTR) [8], the CRAMS (circulation, respiration, abdomen, motor and speech) Scale [9], the Prehospital Index [10], and the ACS-COT field triage criteria, which are believed to be the most widely used in the United States [11].

Several studies have found the judgment of field personnel to be comparable to the performance of certain field triage schemes. Fries and colleagues [12] compared paramedic judgment and the TTR, finding equal effectiveness in terms of predicting which patients required trauma center care. The paramedics identified several patients with severe injuries that were missed by the TTR, but the authors did not examine this further. A combination of judgment and the TTR performed the best, achieving 100% sensitivity, with a specificity of 75% [12]. Emerman and colleagues [13] compared field personnel judgment with the CRAMS Scale, Triage Revision of the Trauma Score, and Prehospital Index in the city of Cleveland, Ohio (USA), and found that the providers' predictions of mortality were as good as the predictions of the three scoring systems, as were predictions of need for immediate operative intervention in certain patients. This may be of importance when considering the value of mass casualty triage schemes, none of which has been compared with simple field personnel judgment.

Mass casualty triage schemes

The START system

The simple triage and rapid treatment (START) system was developed by the Newport Beach Fire and Marine Department and Hoag Hospital in Newport Beach, California, USA in 1983 after three emergency department (ED) staff members noted what they felt was inefficient triage at a school bus crash exercise. The intent of the START system is to identify problems that will lead to death within 1 h: impaired breathing, head injury, and significant hemorrhage. It is reported that at the first test of this system, field personnel triaged mock patients with 93% accuracy after 2 h of training (although accuracy is not defined) [14]. According to the START program's web site, 'After initial training rescuers can triage each victim in 60 seconds or less'. Some observers have indicated that experienced field personnel can triage each victim in less than 30 s [14], and some claim that this level of proficiency can be achieved with only 30 min of training [15].

When adequate transport resources are available, it is the intent of the START system that tagged patients are taken directly from where they were initially found to an ambulance without a secondary triage or treatment beyond opening the airway and controlling external bleeding [14]. Only when transport resources are inadequate are patients to be collected at treatment areas and additional field treatment begun while awaiting additional transport. This is an important consideration when discussing CBRN, as detection, donning of personal protective equipment, and patient decontamination may delay transport, thus disrupting the START paradigm.

Despite claims that it is 'the most effective triage program' [15], there has been remarkably little objective study of the START system. A 2001 paper examined the performance of 109 emergency medical services (EMS) personnel, 78 of whom were basic life support personnel, on a 20-question written test both before and after a 2-h slide and video presentation on the START program [16]. The mean post-intervention score (75%) was significantly better than the mean pre-intervention score (55%, $P < 0.001$). The written test was also repeated 1 month later, to assess skill retention. While advanced life support providers showed no drop in scores (mean 75%

at 1 month vs. mean 76% post-intervention), the basic life support providers did show a small but statistically significant drop (mean 68% at 1 month vs. mean 74% post-intervention, $P < 0.01$) Whether a given provider had previously had any triage or mass casualty incident training had no effect on test scores. It should be noted that the meaning of high scores on a written test such as this one has not been evaluated in terms of predicting actual performance in the field, or, more importantly, effect on patient outcomes.

A pediatric version of START, called JumpSTART, was developed at the Miami (Florida, USA) Children's Hospital in 1995, and modified in 2001. This revision appears to have the 'official' endorsement of the creators of START, through mutual links on web sites and frequent references to each others' systems. One recent article in the literature evaluated the effect of JumpSTART training on the ability of 24 EMS providers and eight school nurses to triage 12 children with simulated injuries into the 'correct' categories, as determined by the authors [17]. As with the study by Risavi *et al.* [16], there is no way to know whether 'correct' triage has any meaning in terms of improved scene operations or outcomes. It is also not known how widely used this system is for training or actual events.

In 1996, Benson and colleagues [18] proposed extending the START system with an additional scheme to be used when transport is delayed for a considerable period of time (hours or, perhaps in the case of a catastrophic earthquake, even days), and patients need re-evaluation at periodic intervals. The secondary assessment of victim endpoint (SAVE) system assesses the survivability of a patient, then estimates the relationship between the resources that will be needed to care for this patient, and the benefits to be expected. Patients are sorted into three categories: those who will survive regardless of whether they receive care, those who will die even with maximal efforts allowed by the limited resources available, and those who will benefit significantly from the austere interventions possible. While very basic care and comfort measures will be made available to patients in all three groups, only the last group will receive more. One exception, using the 'greatest good for the greatest number' principle [19,20], might allow for treatment of a healthcare professional with minor injuries, if this enables that person to provide care for other patients (sometimes referred to as the 'multiplier effect' [19]).

Patients who were sorted by START into the 'red' category are re-assessed first, then patients in the 'yellow' category, then 'green', and then 'black'. This secondary triage determines the appropriateness of interventions beyond those delivered during the START procedure (airway opening and bleeding control), and the order in which patients receive this further care. Only if treatment can reasonably be expected to reduce morbidity or mortality, *and* this treatment will not overly tax the limited personnel and resources available, will the patient be moved to a treatment area. Otherwise, the patient is moved to an observation area for basic care and periodic reassessment. SAVE also involves prioritization for evacuation. To date, there has been no scientific evaluation of the SAVE system.

Other mass casualty triage schemes

Several other field triage systems have been proposed and used. The triage sieve, the method used by the British military for primary triage, uses the same basic criteria as START, except that mental status is omitted. The triage sort, used for secondary triage, resembles the RTS field triage scheme in that the Glasgow Coma Scale (GCS), respiratory rate, and systolic blood pressure are used.

The French use a very different type of triage system. In the field, patients are first categorized as either 'absolute emergencies' or 'relative emergencies'. These two categories are each divided into two subcategories, with patients being labeled as 'extreme emergencies (EE)' or 'first emergencies (U1)', and 'second emergencies (U2)' or 'third emergencies (U3)' [21]. Each category consists of a number of diagnoses, and patients are placed into a category on the basis of their presumptive field diagnosis. For example, cardiopulmonary failure is scored EE, hemorrhagic gluteoperineal injuries and spine injuries with neurological disorders are each scored U1, compensated chest injuries and head injuries with GCS > 12 are considered U2, and burns of < 15% body surface area (BSA) and closed fractures are U3. It seems that a reasonable degree of medical sophistication is needed on the part of the triage officer in making diagnoses. As this role is typically filled by a physician, the French feel that this system allows for dynamic triage during the treatment and evacuation of patients.

An Italian system called the CESIRA protocol was developed in 1990 to account for the fact that Italian law prevents most EMS personnel from certifying death. This system sorts patients into red, yellow, and green categories, but does not include categories for dead or expectant patients [21]. CESIRA is the Italian acronym for the conditions to be evaluated (Coscienza, Emorragie, Shock, Insufficienza respiratia, Rotture ossee, Altro). The authors of an Italian disaster management textbook indicate that this system is less accurate than START (though no data are given to support this assertion), but is necessitated by the local legal structure. This serves to point out that differences in the emergency response system structure (e.g. level or type of EMS provider most likely to actually perform triage in a local event), legal structure, or even liability matters may influence the development, selection, and use of a triage system.

Most recently, a proprietary system called the Sacco triage method has been developed and marketed in the USA. A paper describing the derivation of the system and mathematical simulations used for validation is in press at this time. Compared with the traditional goal of doing the greatest good for the greatest number, the stated goal of the Sacco triage method is to maximize the expected number of survivors. The details of the system have not been published, and are not available at the company's web site (www.sharpthinkers.com), as users must pay to receive this information. This appears to be the only triage system that is not in the public domain. No information is available regarding whether the system is actually in use anywhere.

The Glasgow motor response

Perhaps the simplest proposed mass casualty triage scheme involves assessing only the motor component of the GCS. As early as 1983, it was demonstrated that the motor score accounts for most of the predictive power of the GCS. Using logistic regression techniques on a database of 1197 patients, it was found that there was a strong association between mortality and the first motor score obtained in the ED, but that the addition of data via either the eye or the verbal score did not improve the strength of this association. The motor score alone was actually a slightly better predictor of mortality than the summed GCS ($r = 0.714$ vs. $r = 0.68$, $P < 0.0001$). The authors noted that given the difficulty in applying the GCS in intubated or otherwise non-verbal patients, the simplicity of the motor score would support its superiority [22].

A retrospective study of almost 30 000 patients in the North Carolina (USA) trauma registry demonstrated that this parameter, which the authors called the Glasgow motor response (GMR) score, was almost as good as the trauma score (which was used as the gold standard), and better than the injury severity score (ISS) and the full GCS at identifying risk of death [23]. Simply separating patients into those who could follow simple commands (GMR 6) and those who could not (GMR 1–5) provided the best discriminatory capability, and other reviewers have commented that a scheme that divides patients into only two categories may be more practical than a more complicated, multiple-component scheme [24,25]. (See additional discussion of this below.) While the GMR was significantly associated with mortality ($P < 0.001$), sensitivity was only 59.4%, and the authors conceded that neither the GMR nor the trauma score 'is as good as one would like,' with far from ideal predictive power. The authors suggest that the one-step simplicity of the system was likely its greatest virtue. Such a simple system might be of great value in the CBRN environment, particularly in situations in which the person performing triage must be in level A, B, or C personal protective equipment, limiting the dexterity needed to perform some of the assessments required in other triage systems, such as measuring a victim's blood pressure.

A very similar study, published in 1998 by Ross and colleagues [26], involved a retrospective review of a database of 1410 adult trauma patients who had a prehospital GCS recorded by EMS personnel. The motor component of the GCS performed just as well as the full GCS when compared with the Abbreviated Injury Scale, using the same criteria as the North Carolina study, with a motor score of less than 6 considered positive.

A 2003 study tested the hypothesis that most of the predictive power of the GCS resides in the motor score, with the eye and verbal scores adding little [27]. Using the US National Trauma Data Bank, the investigators examined the records of roughly 200 000 trauma patients. Removing the eye score did not lower the predictive performance of the GCS at all. Removing the verbal score did result in a statistically significant but mathematically minimal lowering of performance [area under the receiver operating characteristics (ROC) curve drops from 0.891 for the GCS to 0.873 for the motor score alone], but given the problems with obtaining an accurate verbal score in certain patients (intubated and inebriated patients in particular, and patients with a language barrier), the authors advocate its removal as well, leaving the motor score only. It was also noted that the motor score held a near-linear relationship with mortality, while the GCS and the eye and verbal scores did not, increasing the intuitive appeal of the motor score.

Most recently, investigators at the Ontario Prehospital Advance Life Support Trial examined the ED records of 795 blunt trauma patients' to compare the RTS, the full GCS, and the motor component of the GCS [28]. For the study's primary outcome measure, survival to discharge, the area under the ROC curve for the motor component of the GCS (0.81) was not distinguishable from that for the full GCS (0.82) or the RTS (0.83). The motor component also accurately predicted the need for intubation in the ED, admission to the intensive care unit, and disability. The authors concluded that the motor score was superior in its predictive validity, while being more efficient and easier to use.

Comparative studies of mass casualty triage schemes

Very little work comparing mass casualty schemes has been performed. A 2001 paper by Garner and colleagues [29] compared the original START scheme, the START system as modified by Benson and colleagues [18] (substituting a palpable radial pulse for assessment of capillary refill), the original triage sieve, the modified triage sieve (again substituting a palpable radial pulse in place of capillary refill), and the triage system used by the Australian medical retrieval service that conducted the study ('Care Flight

Triage'). In a retrospective analysis of 1144 adult trauma patients, the CareFlight triage system performed the best, but differences in sensitivity and specificity were minimal. Of note, it was found that GMR (which was not being tested as an independent triage scheme; area under ROC curve 0.85, 95% confidence interval 0.81–0.90) and systolic blood pressure (area under ROC curve 0.72, 95% confidence interval 0.67–0.77) were the physiologic components that best correlated with severe injury. The authors speculate, however, that CareFlight triage might be a preferable system because it is the most rapid. After excluding the ability to walk, the next two steps are performed simultaneously, in about 10–15 s: having the patient answer a question or follow a simple command, and checking for a palpable radial pulse. The authors indicate that assessing the respiratory rate (as some other mass casualty triage schemes do) or systolic blood pressure would add significant amounts of time. No other studies comparing mass casualty triage schemes have been located.

Comparing and testing mass casualty triage systems

The paucity of literature evaluating mass casualty triage systems may be due to at least three significant difficulties that researchers encounter when attempting to validate or even compare such systems. First, there is no clear 'gold standard' against which to measure the performance of a triage system. Second, the lack of outcomes-based research means that it is essentially unknown whether applying any mass casualty triage system as intended will have a positive effect on patient outcomes. Third, it is difficult to sort out the relative contributions of the triage system and the personnel applying the system. It is thus not clear, when discussing 'testing' a mass casualty triage scheme, if one is testing whether the scheme predicts patient outcomes, whether providers use the scheme accurately, or whether use of the scheme improves outcomes. As the long-term goal of this project is to refine and validate the proposed CBRN mass casualty triage system, and to compare its performance with that of other systems, discussion of these three problems seems warranted.

Lack of a gold standard

Just as no mass casualty triage scheme has become accepted as a gold standard [30], there is no accepted gold standard against which to measure the performance of mass casualty triage schemes [16]. One author has indicated that triage decisions are 'probably only 80% accurate' [31], but what is not stated is how this accuracy is judged. It should be possible to study a triage scheme to determine whether real patients categorized as seriously injured truly are seriously injured; but even here there is no agreed-upon gold standard for what constitutes a seriously injured patient [32]. Studies involving actual trauma patients have used a number of different outcome measures. In developing the TTR, Baxt and colleagues [8] used a resource-based definition of a patient who actually had major trauma: (1) a non-orthopedic operation with positive findings (defined as injuries that could have been life-threatening if not treated) in the first 48 h of admission, (2) in-hospital fluid resuscitation of greater than 1 l or transfusion, to maintain a systolic blood pressure of 90 mmHg or greater, (3) invasive central nervous system monitoring with either a positive head computed tomography scan or documented elevation of the intracranial pressure, or (4) died as a result of the injuries sustained. Fries and colleagues [12] added intensive care unit admission for monitoring of closed head injuries to this definition. In a later study by these same researchers comparing multiple field triage schemes, two different gold standards were used: an ISS of 15 or greater, or either death or survival with a functional deficit, defined as unable to return to full work status, unable to return to work at all, or requiring full-time supportive care [33]. Garner and colleagues [29] used a modified version of Baxt and colleagues' original criteria: criteria 1 was changed to a 6 h window, criteria 2 was modified to add in prehospital fluid administration, and criteria 3 was unchanged. Two additional criteria were added: a procedure to maintain a patent airway or provide assisted ventilation (either prehospital or in the hospital, excluding cases in which ventilatory support was needed solely due to chemical sedation), and decompression of a tension pneumothorax (either prehospital or in the hospital) [29]. All of these seem to reflect patients at imminent risk of death.

Gormican [9] defined major trauma patients as those who died in the ED, or who went directly to the operating theater for general surgery or neurosurgery, while Koehler and colleagues defined major trauma as injuries leading to death within 72 h of injury, or to 'emergency, life-saving' neurosurgery or general surgery within 24 h (pilot study) [10] or 4 h (validation study) [34]. In their study of the role of the mechanism of injury, Knudson and colleagues [35] used four criteria for 'significant injuries': death, hospitalization for greater than three days, an ED trauma score of ≤ 14, or an ISS of > 15. In their work comparing 11 different scoring systems, Hedges and colleagues [32] defined patients 'desirable for trauma center triage' as those with absence of vital signs in the prehospital setting, death in the ED or later in the hospital, immediate surgery other than for orthopedic extremity injury, or immediate admission to the intensive care unit. While these authors specifically indicated that these criteria were meant to be similar to criteria used in other, similar studies, it is doubtful that they can be considered a true 'gold standard'.

In their military study, Burkle and colleagues [36] deemed triage to be correct if those patients categorized as 'immediate' by the RTS were placed on the initial

surgical priority list by the assessment and stabilization team, and were not re-categorized as expectant while still in the assessment and stabilization area.

In another military study, designed to determine what types of military personnel should be performing combat triage, Janousek and colleagues [37] administered a 21-scenario written exam to military physicians, nurses, and medics/corpsmen. The seven patients in each of three scenarios (standard combat scenario, nuclear/biological/chemical scenario, and peace-time scenario) were to be triaged into the standard NATO categories of immediate, delayed, minimal, and expectant. The same 21-scenario written exam was used in a similar study of military nurses a few years later [38]. While not explicitly stating how they determined what the 'correct' answers were for each scenario, the authors of the survey indicated that the cases 'matched the recommendations of standard triage references,' citing six popular texts on triage and disaster medicine. They also indicate that borderline cases were avoided in favor of simplicity and clarity, but they do mention as a possible limitation of the study that different study participants may have interpreted the patient presentations differently.

So while many different gold standards have been used, certain themes emerge when they are examined, with resource-based definitions (e.g. types of operations needed) and score-based definitions (e.g. ISS) predominating. Having an agreed-upon gold standard would allow researchers to test and compare triage schemes, and to determine features such as the sensitivity and specificity of such schemes (Appendix 2). To further complicate matters, Wesson and Scorpio [11] note that there is not even an accepted definition of a 'true positive' in the context of triage, and while serious, life-threatening injuries are of course the focus of most studies in this area, other variables, including the need for specialized services that in many areas are only available at trauma centers (e.g., reimplantation, neurosurgery, pediatric surgery, and pediatric critical care), are also relevant when considering field triage. The implication here is that 'true positives' might include those patients who are not at risk of dying, but who need the trauma center for other reasons.

Meredith and colleagues [23] have similarly postulated that there are two types of patients needing the resources of a trauma center: those unstable patients for whom urgent care could be life-saving (the example of a patient in hypovolemic shock from a major vascular injury is given), and those who are stable but have complex injuries such that the specialized resources of a trauma center could reasonably be expected to lead to better outcomes (the example of a stable patient with a complex facial injury is given; presumably this patient's airway is not involved). Meredith *et al.* suggest that, even in a single-patient scenario, it is less important for a triage tool to accurately identify the second type of patient, as the patient could reasonably be transferred to the trauma center at a later time. It seems reasonable to extend this suggestion to the mass casualty or disaster situation, relying on secondary triage at a later time to transfer such patients to tertiary facilities as resources permit. For the purposes of this discussion, 'true positives' will be limited to those patients at imminent risk of death, and thus a 'gold standard' need only reflect patients who truly were at such risk.

Lack of outcomes-based research

Patient outcome in 'real life'circumstances would seem to be the logical gold standard when judging the performance of triage schemes, but this is obviously very difficult to test, and also precludes testing triage schemes with drills of any sort. Given the complexity of the medical care system, it likely will be fruitless to compare outcomes from different disasters. For example, if triage scheme A is used to triage 50 trauma patients from a bus crash in rural Albania, and triage scheme B is used to triage 45 patients from a building collapse in urban Paris, it probably will not be reasonable to compare patient outcomes to judge the relative merits of the two triage schemes, due to differences in the types of injuries sustained, the types of EMS agencies and providers who respond, transport intervals, types and numbers of hospitals available, etc. Even if the events are very similar, the injuries are likely to be different, as are the medical care systems that treat the patients.

A 1986 study examining improvements in the trauma triage system of Orange County, California, USA, used two formal definitions of a major trauma victim (ISS $\geq$ 10 with hospital stay of 3 days or more; ISS > 15 – both retrospectively determined), but informally defined such patients as those 'having a magnitude of injury in which the probability for survival would be increased if treated in a trauma center' [39]. This dichotomy summarizes the issues here, in that what we really want to study and predict are outcomes (better survival at a trauma center, for example), but what we often have to settle for are surrogates. While ISS is meant to serve as a quality 'filter,' and correlates in a fairly linear fashion with mortality, morbidity, hospital stay, and other measures of severity, it is still a surrogate for true outcomes, and can only be determined retrospectively, days to weeks after the injuries occur.

It is likely possible to study the performance of specific components of a mass casualty response system using real casualties from real disasters, and even to examine patient outcomes in this context. As an example, May and coworkers [40] retrospectively examined the ability of a regional trauma system in general, and its central communication system specifically, to accurately triage injured patients following a major tornado in the Birmingham, Alabama, USA, region in April 1998. Their major findings indicated that of 224 injured patients transported to nine of the 10 hospitals participating in the regional

trauma system, no patients with life-threatening injuries (ISS > 20) went to hospitals other than level I trauma centers, and only two patients who survived the initial impact died later, both of whom had severe closed head injuries. While the authors concluded that their triage and communications system worked appropriately, this study focused much more on structure and process than on outcome. It is also important to recognize that outcomes will depend on many things other than triage, including ED care, operative interventions, in-hospital care, and rehabilitiation. This further complicates the assessment of the success of a triage system.

The triage scheme and its application

If the end result of triage is not what was expected (e.g. more over-triage or under-triage than was anticipated) – whether this be in an artificial testing environment or in an actual disaster – it is possible that the triage scheme being used is not effective, that the field personnel are not applying the scheme correctly, or both. Without knowing the level of compliance of the field personnel in applying the scheme, it is not possible to judge the performance of the scheme. Regardless of the direction from which one approaches the problem (scheme performance vs. personnel performance), the lack of a gold standard will affect the ability of researchers to test triage schemes. Even if it can be demonstrated that the field personnel who are applying the scheme when it is tested are applying it correctly, it will be difficult to determine whether the triage assignments made are 'correct' unless the system is applied to real patients, with success judged by actual outcomes. It must also be recognized that triage is a dynamic process, and that patients may improve or deteriorate over time, further complicating both patient evaluation and treatment, and assessment of the triage system itself. Assessment of (and ensuring) personnel compliance with a triage scheme, however, is a necessary first step in evaluating any scheme's performance.

Mass casualty schemes in the chemical, biological, radiological, or nuclear environment

It has been suggested that the ideal mass-casualty triage scheme would have the following characteristics [21]:

(1) Easily memorized.
(2) Rapidly applied.
(3) Little inter-rater variability: the same category would be assigned if many rescuers applied the system to the same patient.
(4) Applicable by rescuers with a variety of backgrounds and levels of education and experience.
(5) Reliable in determining priorities correctly.

Another author states that the most desirable features of a mass casualty triage tool are simplicity, accuracy, reproducibility, and rapidity [23]. The ideal CBRN-capable mass casualty triage scheme should also have these characteristics, but in addition, should account for the clinical implications of the CBRN agent(s) involved. Before any such scheme is applied, triage personnel must first detect the presence of the CBRN agent(s), and determine whether entry into the casualty area is safe, either with or without personal protective equipment. It also seems reasonable to expect that a mass casualty triage scheme be easily applied under austere conditions.

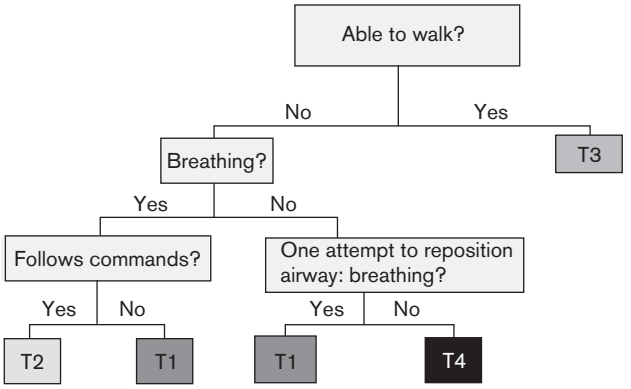
In developing a set of CBRN-capable mass casualty triage schemes, several options exist for a starting point. It could be argued that one should modify the START system, as this is perhaps the most widely used system, and might thus require less re-training than if a new system were introduced to personnel already trained in the START system. It could also be argued that one should use the CareFlight system, as there are some objective data to support its superiority to START, and because it likely is the fastest of the five multi-category triage schemes tested by Garner and colleagues [29]. Or it could be argued that one should use the GCS motor component as the starting point for the system, as there are several studies supporting its use. It is the simplest of the systems discussed above, and is possibly even faster than the CareFlight system. Using the GMR would also minimize the amount of medical assessment needed, allowing the triage personnel to focus on the CBRN issues at hand. Given all of these factors, the START system and the GMR concepts will be used as the basis of the proposed CBRN-capable mass casualty triage schemes.

Time and complexity may be more important in the CBRN environment than in 'ordinary' mass casualty incidents. It seems logical to assume (though there are no data to support this assumption) that the CBRN environment will make triage more difficult, thus making simplicity all the more important. In other words, a triage algorithm that is somewhat difficult to apply under optimal circumstances (perhaps a school bus crash with 25 injured teenagers on a dry road in good weather) will likely be much more difficult to apply under CBRN circumstances (such as a 'dirty bomb' explosion during a college graduation ceremony, or the same school bus that crashed into a tanker of anhydrous ammonia, which is leaking onto the roadway). It thus seems that any CBRN-capable triage system must be at least as simple as its non-CBRN counterpart. The addition of one or two 'steps' somewhere in the algorithm may be acceptable, but adding significant layers of complication is not. The goal shall be to keep the CBRN triage scheme as simple as possible.

As the basic template for the proposed CBRN-capable mass casualty triage scheme, the START system is modified as follows (Fig. 1):

(1) The assessment of respiratory rate is eliminated. It will be replaced with a subjective assessment of the

Fig. 1



Basic trauma triage template.

patient's respiratory status in the *chemical* algorithm, in which, for example, the quality of respirations may be more important than the respiratory rate (e.g. for choking agents). For the biological, radiological, and nuclear algorithms, no respiratory assessment is needed during initial field triage.

(2) The assessment of the radial pulse (or capillary refill) is eliminated, with the last two steps of the START algorithm being replaced with assessment of the GMR.

While the resulting algorithm may seem overly simplistic, it is designed to serve as a common starting point for the individual CBRN algorithms. Specific items will be added to this basic template for each algorithm as needed, and it is thus important to start with as simple a decision tree as possible. Once tested against other mass casualty triage schemes (see 'Future Directions' below), perhaps it will be found that this basic template performs as well as or better than the other common systems. This would allow this basic template to also be used for non-CBRN mass casualty triage, eliminating the need for field personnel to have one system (perhaps START or the Triage Sieve) for non-CBRN situations, and another system (the algorithms proposed below) for CBRN situations.

Proposed chemical, biological, radiological, or nuclear-capable mass casualty triage schemes

Chemical

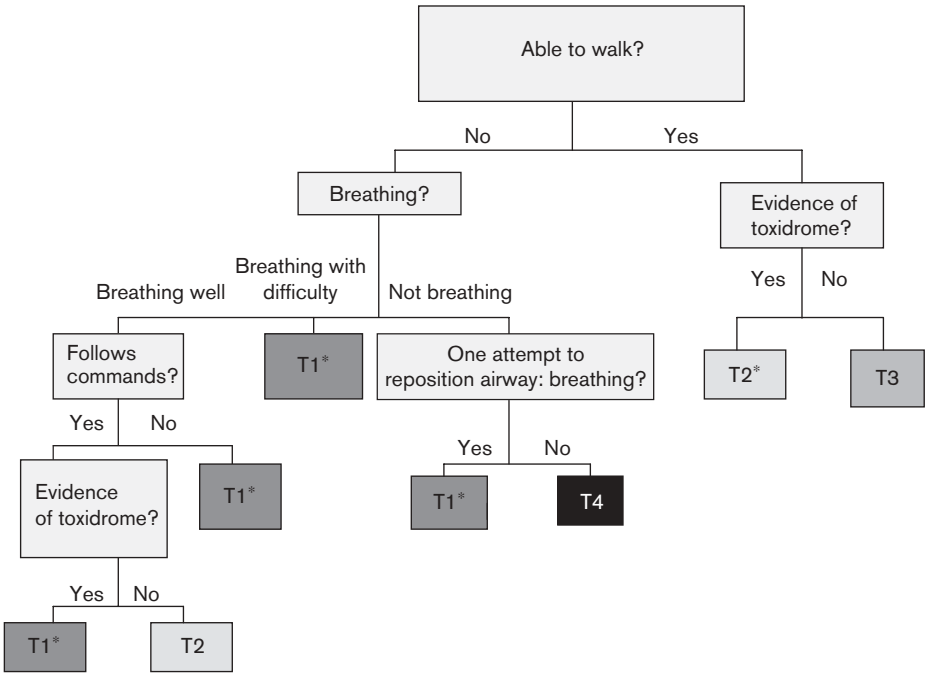
Several important differences are observed between chemical and other CBRN exposures. The first is that the agent itself can cause immediate, serious (even fatal) illness even in patients with no traumatic injuries. By the time a rescuer reaches a chemically exposed or contaminated patient, that patient may already be showing evidence of a toxidrome, or be critically intoxicated or even dead. Assessment for evidence of a toxidrome is a key additional step to be performed when assessing a chemically exposed patient.

Hazardous materials exist that exert their clinical influences in a less rapid manner. Phosgene, for example, has a much longer latency period than does cyanide. One of the stated criticisms of the START system (and presumably other similar systems) is that patients with injuries due to certain chemical exposures may deteriorate rapidly after initially being triaged as T2 or even T3, as a result of the latency of the clinical effects [21]. It thus seems that adding a step to the algorithm to examine for a toxidrome would be a reasonable use of time even in the 'walking wounded' (T3), to avoid undertriage. It is also likely that frequent re-assessment will be needed, to monitor for deterioration due to contaminant latency.

The second major difference is that respiratory failure is a serious (and often the primary) threat with many chemical exposures [1,41–44]. A variety of mechanisms, including respiratory muscle paralysis, bronchospasm, excess secretions in the tracheobronchial tree, pulmonary edema at the alveolar level, and impairment of cellular respiration at the mitochondrial level, may be involved [41]. While a scoring system called the Breathing Assessment Score in Emergencies (BASE) was devised in the mid-1990s to assess the degree of respiratory distress, with a pilot project involving 359 prehospital patients presented at an international meeting in 1998 [41], it does not appear that further work has been done to develop and validate this system in the chemical environment. Accordingly, the chemical triage algorithm proposed here (Fig. 2) involves a simple subjective assessment of the patient's overall respiratory status (breathing well/breathing with difficulty/not breathing). Given the preliminary data showing better prediction of the need for intubation when compared with GCS [45], further work on the BASE system may allow for its use in place of this subjective assessment.

Third, there is generally a greater threat of secondary contamination (also known as transmissibility) to rescuers from chemical agents than from radiation or biological agents, particularly those chemicals that are persistent. Before initiating triage, it must be ascertained that rescuers can safely enter the area, either with or without personal protective equipment. This may cause organizational and logistical difficulties, particularly with regard to the training needed to utilize and safely operate in personal protective equipment, and the likelihood of a multi-agency response. Issues may arise regarding which agency's personnel are authorized to function in a contaminated area. As an example, the British 'Structured Approach to Chemical Casualties' course teaches that only fire personnel may enter the hot zone to extricate

Fig. 2



Trauma and chemical triage. *Give antidote if available and logistically feasible. Decontaminate all patients prior to transport.

victims, except under unspecified 'extraordinary circumstances'. Primary triage, using the triage sieve, is performed by a triage officer in full personal protective equipment at the warm zone, prior to decontamination. While not clearly specified in the course manual, it appears that the purpose of this primary triage is (1) to decide which patients need immediate, life-saving care before and during decontamination and (2) to determine the order in which patients are decontaminated. Only airway-opening maneuvers, manual cervical spine immobilization, bag–valve–mask ventilation, and direct pressure on bleeding wounds are to be performed before and during decontamination. Patients are then re-triaged after decontamination for additional care and transport [46]. A similar system used by the French involves 'specially trained physicians wearing protective suits' to provide triage and advanced life support in the hot zone [47].

It must be recognized that patients (even injured patients) may bypass the established zones and decontamination system, and present directly to EMS personnel arriving on the scene. In order to avoid secondary contamination of responding personnel, either it must be determined whether these patients are themselves contaminated, or it must be determined that such patients will undergo decontamination before interaction with medical personnel. Systems are in place, particularly in the military, for screening arriving casualties for signs of contamination. For example, Burkle and colleagues [36] report that at their combat field trauma center in Kuwait, '…all casualties were questioned rapidly on possible exposure and were screened by vesicant and nerve gas detection devices at the helicopter pad, the weapons search area, and the triage area'. It does not appear that such programs are available yet in the civilian sector.

In the British program described above, the triage sieve is used with the minimal modification that the final step (assessment of capillary refill or radial pulse) is performed only if the patient is traumatically injured and contaminated. In keeping with the basic template proposed here, however, this step is omitted from the proposed chemical algorithm for all patients.

The British system also offers specific guidelines (including antidotes, where available) for handling exposures to organophosphates, mustard gas, phosgene, chlorine, and hydrogen cyanide. When antidotes exist for given exposures, the question arises as to when to administer them: in the hot zone, prior to decontamination; in the warm zone, during triage for decontamination; or after decontamination. While at least one textbook recommends adding antidotes to the traditional ABCs (airway/breathing/circulation) that are considered for the T1 patient, no recommendation is made regarding when to administer antidotes relative to decontamination [48].

One author recommends that both basic and advanced treatment, including antidotes, be provided prior to decontamination, to avoid the 'potentially life-threatening delays in patient management' that might otherwise occur [49], and another indicates that 'emergency life-saving procedures take precedence over any other decontamination' [50]. The French system described above notes that it typically takes at least an hour to set up the decontamination zone, and specifies that some casualties will need treatment before or during decontamination. It appears that the physicians involved are providing both triage and antidote treatment, and while antidotes are generally provided at the system's Advanced Medical Post, there is the provision to send physicians into the hot zone for rapid administration before and during decontamination [47]. One proposed system for the management of chemical casualties at the hospital involves intubation of patients with respiratory failure by specialized personnel in level C personal protective equipment prior to decontamination [51], though it does not appear to have been suggested that this concept be employed in the field. Regardless of location, this paradigm of providing triage and treatment simultaneously mirrors the provision of two limited treatments (opening the airway and controlling major hemorrhage) that are found in many mass casualty triage schemes, including START. These can likely be justified in that they can be performed rapidly and may prevent rapid deterioration of a patient to a more critical triage category. With limited numbers of personnel, however, these interventions should not measurably delay triage of other patients.

Noting that there are only two time-dependent antidotes [48], and in the absence of any scientific evidence to guide such a decision, the proposed chemical algorithm recommends that antidotes be administered as soon as practical. It may be practical for the triage officer to administer a Mark I (NAAK) kit (Meridian Medical Technologies Inc., Columbia, Maryland, USA) to a patient exhibiting a toxidrome consistent with organophosphate toxicity while that patient awaits decontamination. It may be impractical for a triage officer to administer hydroxocobalamin to a patient who has signs consistent with cyanide toxicity, as this medication must be administered intravenously, with repeat doses often needed. Scene logistics will largely determine the appropriate timing of antidotes, and as the responder-to-patient ratios change and additional advanced providers arrive, the management approach may be altered, allowing for more treatment.

It may be reasonable to consider whether triage personnel should initiate decontamination by removing patients' clothing. Simply removing the clothing will eliminate up to 80% of the contaminants [52,53], especially if the substance is a vapor or gas [54]. Whether triage personnel can do this will depend on the number and severity of other casualties, and perhaps the type of personal protective equipment they must wear. If the numbers of patients are large, the person(s) performing triage will need to move on quickly, and leave the removal of clothing to treatment personnel, or to the patients themselves if they are able to do this. An adequate supply of paper gowns or blankets will be needed for patient privacy [55], adding another layer of logistic complexity. Hence, while clearly not a priority for triage personnel, and while not incorporated into the proposed algorithm, clothing removal may be a reasonable consideration in certain circumstances.

Radiation

An event such as the explosion of a radiological dispersion device (RDD), or 'dirty bomb,' has the potential to create a significant number of patients with severe traumatic injuries (as would be seen with conventional explosives) who also sustain radiation exposure and/or contamination. While it is unlikely that the radiation involved in an RDD would be the primary cause of death of any victims [56], the radiation has the potential to worsen conventional injuries, complicate their treatment, and negatively contribute to the psychological aspects of the event. While at least one triage algorithm for use at the ED has been proposed [57], it does not appear that any similar algorithms for field use have been published in the peer-reviewed literature.

The difference between *exposure* and *contamination* is relevant to the concept of triage [58]. If the patient has simply been exposed to radiation, but is no longer exposed and is not contaminated, then the patient is not a danger to medical personnel, just as a patient who has recently completed a computed tomography scan is not a danger to those nearby. In other words, there is no transmissibility after exposure. A patient who is contaminated (e.g. who has flecks of radioactive material embedded in the clothing and skin) does pose a danger to medical personnel, because they will be exposed to the patient as a radiation source. It is generally accepted, however, that this danger is minimal [58,59], and is less than the dangers posed by secondary contamination with chemical hazardous materials [60]. In addition to being exposed to radiation from contaminated patients, triage personnel will also need to consider the possibility of exposure from nearby radioactive debris, and from inhalation of airborne radioactive materials. Hence, the first decisions to be made do not involve the actual triage process, but rather whether triage personnel can safely work in the area, and what personal protective equipment, if any, they need to wear. It has been recommended that the personnel performing triage on these patients wear clothing that provides strict isolation, as well as double gloves, with careful changing of the outer layer of gloves after attending to each patient to avoid

cross-contamination in the event that some patients are indeed contaminated [61]. Consideration has also recently been directed toward whether rescuers should be premedicated with certain radioprotective medications such as iodine.

In general, trauma patients who have been exposed to or contaminated by radiation should be treated on the basis of the severity of their conventional injuries [59–61]. While the radiation may influence the timing of surgical procedures and other, later interventions, it typically should not influence initial stabilization efforts. Accordingly, triage itself will not need to be adjusted significantly beyond the basic template.

Three other considerations arise once the patient has been initially triaged. First, as with chemical contamination, should the person performing triage initiate decontamination by removing the patient's clothing, or instruct the patient in self-removal of clothing? Clothing removal, as is the case with many types of chemical contamination [52,54,62], will remove most radioactive contamination (perhaps 90%) [58], but as with chemical scenarios, while there are certain circumstances in which clothing removal by triage personnel may be reasonable, it does not seem to be a feasible 'standard' part of the triage scheme. A key point is that triage and care of injured patients must take priority over decontamination [61].

Second, if the patient is still being exposed to radiation (perhaps nearby debris from the RDD), and assuming that there is no easy way to eliminate the source of exposure, should the person performing triage either move the patient away from the radiation, or somehow shield the patient from further exposure? Moving the patient likely takes more time and physical effort than is compatible with the concept of rapid triage of multiple patients, particularly when responder-to-patient ratios are low early in the response. Most often, the task of moving the patients away from the source of radiation will be accomplished by those who are moving the patients to the collection and treatment areas. It will likely be impractical to adequately shield the patients, because one would expect γ radiation to be present from β decay of materials such as Cs-137 or Co-60 [63]. A blanket, whether made of cloth or mylar, will not adequately protect from these highly penetrating particles.

Third, should contaminated patients be decontaminated prior to transport? It should first be recognized that radiation decontamination is somewhat different from chemical decontamination, and that additional equipment and expertise are required to determine whether decontamination has been adequate. Second, the risk to medical personnel posed by treating contaminated patients is minimal, so decontamination is not likely to be needed to protect transport and hospital-based workers [61]. Fong [60] indicates that field decontamination should be limited to removal of clothing, and wrapping the patient in several sheets. Issues of facility contamination (to ambulances and hospitals), however, can be avoided if patients are adequately decontaminated at the scene. Berger and colleagues [61] have recommended that prehospital decontamination be undertaken 'except for victims of serious trauma'. Similarly, one hospital-based triage scheme recommends stabilization before decontamination for 'severely injured' patients [57]. The recommendation made here (Fig. 3) is that contaminated patients be decontaminated prior to transport unless logistically unfeasible (proper equipment and expertise not available, for example), with the exception of T1 patients who should be transported immediately. It is important that receiving hospitals be advised of the contamination status of patients.

In summary, it does not appear that any substantial revisions would need to be made to a mass casualty triage scheme to account for radiation exposure. The primary considerations are outside the actual triage process and include the following:

(1) Can triage personnel safely enter the area to triage patients?
(2) Are personal protective equipment or radioprotectant premedication needed by triage personnel, and if so, what types?
(3) Can triage personnel take the time to either disrobe patients (to begin gross decontamination and reduce ongoing exposure) or move patients (if still exposed to a radiation source)? These actions may be acceptable under certain circumstances, but should not be considered routine.
(4) Should decontamination be undertaken prior to transport? This will depend largely on logistical factors, including availability of transport resources, equipment, and expertise.

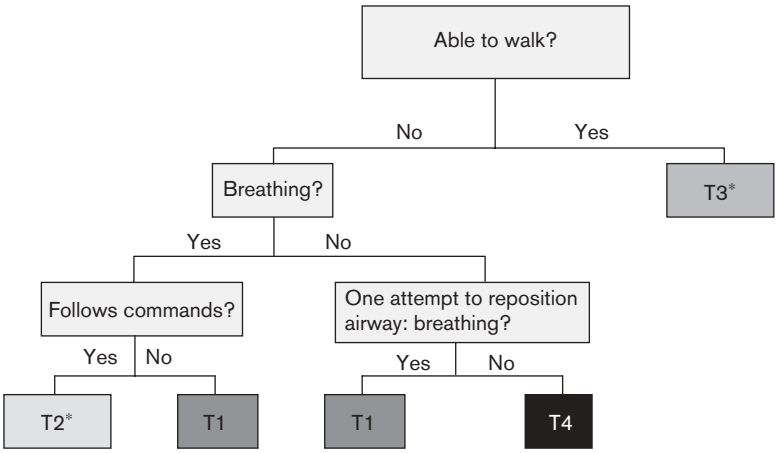
Nuclear

In the case of a nuclear explosion, three types of physical injuries will be seen:

(1) Blast injuries (primary, secondary, tertiary, and quaternary).
(2) Thermal radiation, causing significant burns.
(3) Ionizing radiation, with continued exposure to victims and rescuers in the form of residual radioactivity from fallout.

From a practical perspective, patients who are close enough to the detonation source to receive enough of an ionizing radiation dose to cause acute radiation sickness will be in the blast lethal area, as the blast lethal area has a radius roughly twice that of the area where a 'survival possible' exposure of 2–4.5 Gy occurs [64].

Fig. 3



Trauma and radiation/nuclear triage. *T2 and T3 patients should be assessed for contamination, and if contaminated should undergo decontamination prior to transport unless logistically unfeasible. T1 patients may be assessed for contamination and then decontaminated only if transport resources are not available. Gross decontamination of T1 patients should be completed prior to transport if fallout is a concern following a nuclear detonation.

Survivors of nuclear explosions can essentially be divided into three categories. The first category includes patients with thermal burns alone. The World Health Organization recommends prioritizing patients with deep burns of up to 50% BSA. The second category consists of patients with both burns and radiation injury. Victims with burns of greater than 30% BSA and exposure to more than 4 Gy ionizing radiation have essentially no chance of survival, while burns of $< 10\%$ BSA in patients with exposure to less than 2 Gy ionizing radiation typically do quite well. Unfortunately, it is difficult to assess the dose of ionizing radiation in the field [56], and while time to emesis provides a rough guide (with a dose of at least 3.5 Gy likely if time to emesis is less than 4 h) [58], timed hematologic evaluation is needed to allow for accurate radiation dosimetry. The third category includes patients with burns, radiation injuries, and other physical trauma. The prognosis here is generally worse than for patients with comparable physical trauma alone, and given the likely large number of patients to care for, it is recommended that complex, resource-intensive procedures such as thoracotomy and craniotomy be withheld in favor of caring for multiple patients whose chances of survival are better [64].

As with the non-nuclear radiation injuries discussed above, care of burns and physical trauma should take priority over radiation issues [64]. Clothing removal and gross decontamination, to remove fallout [65], should likely be accomplished in the field for T2 and T3 patients, and possibly for T1 patients as well, given the risk of β burns and radioiodine uptake. Gross decontamination is simpler than the more detailed decontamination needed for patients with radioactive debris embedded in their skin, as may occur after an RDD explosion, involving only a thorough flush with water. It has been suggested that the color magenta, which is used in the placarding of radioactive materials, be used to designate patients with radioactive contamination [65]. This recommendation, however, has yet to be widely adopted.

Given the similarities between radiation and nuclear casualties, a single triage algorithm is proposed for both types (Fig. 3).

Biological

In the event of a covert release of a biological weapon, patients will present to the healthcare system with signs and symptoms of illness after a latency period that varies from agent to agent, but is typically on the order of days, as opposed to minutes or hours as with most chemical agents. The type of mass casualty triage being discussed in this paper will not be applicable to such an event, and in fact a very different type of triage scheme has recently been proposed for such events, involving categorizing members of the population as susceptible, exposed, infectious, removed, or vaccinated (leading to the acronym SEIRV) [66]. In the event of an overt release, however, or when the source of a biological agent is ascertained (as with the anthrax episodes of autumn 2001, where certain postal sorting centers were determined to be the likely site of dispersal), the emergency response system may need to deal with patients who may (or may not) be contaminated with a biological agent, and may also have sustained physical trauma due to an explosion or fire (e.g. from a dispersal device), or panic and stampede (e.g. after an announced release in an arena or other site with limited means of egress relative to the

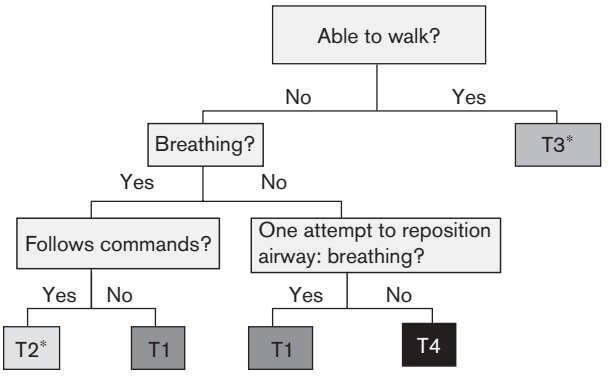
number of occupants, though historically panic is rare in disasters). In such circumstances, detection and confirmation of contagion is essentially impossible in the short time-frame needed to make decisions regarding need for responder personal protective equipment; responding agencies and personnel will have to assume that a biological agent is indeed involved. In essence, the two types of triage systems being discussed (the SEIRV system for covert releases, and the system proposed here for overt releases involving physical trauma) are mutually exclusive, to be used in very different circumstances.

Regarding personal protective equipment for responders to an overt release, a high-efficiency particulate air filter respirator will provide respiratory protection against biological weapons, although one disaster medicine text recommends the use of a full-face respirator to provide adequate mucous membrane protection as well [67]. Protective clothing, as would be used for chemical hazards, is typically not recommended, as intact skin provides adequate protection for biological weapons other than mycotoxins [67].

In general, concepts regarding biological decontamination are not as well developed as those for chemical decontamination, and in some cases, chemical decontamination methods have been used to perform biological decontamination simply because they were known and available [68]. In contrast to chemical agents, however, decontamination is relatively less important as biological agents are non-volatile and generally not dermally active, and the risk of re-aerosolization after a dispersal vapor settles on patients or environmental services is felt to be low.

No formal recommendations have been located regarding the need for decontamination of trauma patients with possible biological weapons exposure prior to transport to the hospital. It has been stated that unlike chemical terrorism, decontamination is not necessary in most cases of biological terrorism [69]. A working group of the US Centers for Disease Control has stated that decontamination 'in most cases will not be necessary' [70]. For a known or suspected anthrax release, it has been recommended that persons in direct contact with the involved substance should wash with soap and water, but even for these exposed individuals, further decontamination efforts are not indicated [71]. It has also been noted that the efficacy of disinfection with sodium hypochlorite is questionable [68], and the Center for Disease Control feels that this is an unsafe practice that should be avoided [70]. It is thus proposed here that as with radiation, treatment and prioritization be directed at conventional trauma. If resources are readily available, it may be reasonable to decontaminate T2 and T3 patients with standard soap and water prior to transport, and T1 patients only if transport resources are not available (Fig. 4).

Fig. 4



Trauma and biological triage. *Consider soap-and-water decontamination for T2 and T3 patients. Decontaminate T1 patients only if transport resources are not available.

Future directions

This work suggests several directions for further development and research.

(1) Field trial of proposed triage schemes

The first pilot test of the proposed CBRN-capable system was held on 27 April 2005 at the Tweed-New Haven Airport in Connecticut, USA. A manuscript is in preparation that will describe the results of this pilot test.

(2) Simulation for testing of mass casualty triage schemes

The intended long-range plan for this project involves the development of a computer simulation model, to allow for relatively rigorous testing of existing mass casualty triage schemes, and improvement and validation of the proposed CBRN-capable mass casualty triage scheme. Through computer simulation using a virtual reality audiovisual system, it is possible to replicate a disaster as many times as needed, presenting the exact same patients to as many responders as one wishes to test. Possible applications include:

(a) Inter-rater reliability: The same disaster with the same group of patients can be presented to a large number of providers, one at a time, to determine whether similar triage categories are assigned by providers with various (or identical) levels of training.
(b) Comparison of triage scheme accuracy: Simulated patients can be triaged using as many triage schemes as the investigator wishes to compare. The problem of a gold standard arises here, as the investigator will need to determine the 'correct' triage assignment for each fictional patient, to compare performance of the various triage schemes.
(c) Training: Computer simulation can be used to determine how much training is needed before a

given triage scheme is correctly applied, or whether a given student is now applying the scheme correctly (again taking into account the gold standard issue).

(d) Assessment of the utility of the GMR: Hirshberg and colleagues [24] have commented that 'in the real world (as opposed to during disaster drills), it is impossible to distinguish between casualties requiring immediate and delayed treatment by means of a rapid and cursory examination of a few seconds…. Thus, a simplified triage scheme with only 2 categories (sick or not sick; i.e., patients requiring care in shock rooms and all others) may be a more practical alternative…than an elaborate multi-component scheme'. It seems likely, however, that such a system might end up trading off speed for accuracy. In other words, while a two-category system is almost certainly faster, it by its very nature may not provide as much discrimination capability as a four or five-category system. Kennedy *et al.* [72] suggest that 'the use of a greater number of categories probably allows for greater precision in determining who needs the most urgent care', but data to support this are lacking. If in fact GMR is as accurate as any more complicated scheme, with comparable sensitivity, specificity, and predictive values, then it is almost certainly preferable because of its simplicity and rapidity. Computer simulation can be used to test GMR, both on its own merits and in comparison to other triage schemes. Speed as well as accuracy can be tested.

Conclusions

A mass casualty triage scheme is proposed that accounts for CBRN contamination of victims. The three protocols (chemical, radiation/nuclear, biological) are based on a common, simplified triage template that focuses on assessments that can be carried out quickly and easily by field personnel wearing personal protective equipment as indicated in a hazardous environment. The scheme attempts to balance the need to spend as little time as possible with each patient, with the need to take additional selected actions for viable patients. Refinement and validation are needed.

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Appendix 1: Terminology notes

'Disaster': the definition from the European Master of Disaster Medicine program is used: an event that results in casualties (physical, mental, and social) that overwhelm the medical response capacity (medical and public healthcare) of the affected area; an event that results in an imbalance between the medical response capacity (medical and public healthcare) and the immediately available recourses in the affected area to manage the casualties (physical, mental, and social).

'Mass casualty incident': the definition proposed in *Prehospital Disaster Medicine* is used: '… may have the same magnitude in terms of human life and suffering [as a disaster], but does not destroy the infrastructure of the society. The impact of such events may exceed that of disasters, but the infrastructure remains intact and mechanisms can be developed within the infrastructure to cope with the circumstances'.

'Field triage': a term found in the ACS-COT's 1986 paper establishing trauma triage decision schemes. Refers to field personnel making 'an estimation of injury severity at the scene of the accident and the subsequent matching of patient needs with available resources'.

'Interhospital triage': a term found in the ACS-COT's 1986 paper establishing trauma triage decision schemes. Used by ACS-COT in the context of triage criteria for patients who should be considered for transfer to 'high level centers' for advanced, specialized care.

'Mass casualty triage': a term found in the ACS-COT's 1986 paper establishing trauma triage decision schemes. Not discussed further in that paper; used here to refer to the process of sorting and prioritizing large numbers of patients at a mass casualty incident or disaster.

Triage categories:

The European system (T1–T4) is used throughout the paper: See below.

'T' designation	NATO designation	US color code
T1	Immediate	Red
T2	Delayed	Yellow
T3	Minimal	Green
T4	Expectant	Black

Appendix 2: Statistical terminology

See below.

	Seriously injured	Not seriously injured
Triaged as seriously injured	True positive (TP)	False positive (FP)
Triaged as not seriously injured	False negative (FN)	True negative (TN)

Sensitivity = TP/(TP + FN).
Specificity = TN/(TN + FP).
Positive predictive value = TP/(TP + FP).
Negative predictive value = TN/(TN + FN).

Goal: to reduce false negatives (under-triage) as much as possible, without having excessive false positives (over-triage). Under-triage is a medical problem, in that unnecessary morbidity and mortality can be expected, whereas over-triage is primarily an economic and political problem [30], unless the over-triage burdens the trauma center to a degree that it is unable to provide appropriate care for seriously injured patients. In general, a significantly higher level of over-triage than under-triage is acceptable, with one source indicating that for conventional, single trauma patients (not mass casualty situations), it is desirable to keep under-triage to less than 5% (sensitivity 95% or greater), and over-triage to less than 50% (specificity 50% or greater) [35]. No similar estimates of acceptable over-triage and under-triage for mass casualty events or disasters have been located.