Effectiveness of and Adherence to Triage Algorithms During Prehospital Response to Mass Casualty Incidents

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ABSTRACT

Mass casualty incidents (MCIs) can rapidly exhaust available resources and demand the prioritization of medical response efforts and materials. Principles of triage (i.e., sorting) from the 18th century have evolved into a number of modern-day triage algorithms designed to systematically train responders managing these chaotic events. We reviewed reports and studies of MCIs to determine the use and efficacy of triage algorithms. Despite efforts to standardize MCI responses and improve the triage process, studies and recent experience demonstrate that these methods have limited accuracy and are infrequently used.

Keywords: *mass casualty; trauma*

Introduction

Multiple triage systems have been proposed to sort patients quickly and efficiently based on various clinical factors. Since the American Revolution through the Napoleonic Wars and into the modern era, healthcare providers in different environments have endeavored to optimize patient outcomes by improving the system of triage, transport, and delivery of life-saving interventions (LSIs).[1–7]

The conventional approach to mass casualty incidents (MCIs) employs formal algorithms to sort and prioritize casualties using clinical parameters. These algorithms use an acuity or color code designation to identify presumed levels of critical care: Minimal (green), Delayed (yellow), Immediate (red), and Expectant/Deceased (black or blue). Many guidelines suggest appropriate LSIs and timing of transportation based on these catagories.[8–13]

Although the use of triage systems and algorithms seems logical, it is unclear whether they are effective during the chaos and danger of real-world MCIs, given the limited availability of providers and resources, variable personnel training and experience, and decentralized leadership. We reviewed the literature regarding the effectiveness and practicality of various triage algorithms in the civilian prehospital setting.

Methods

The MEDLINE, Scopus, and Google Scholar databases were searched for peer-reviewed and gray literature on prehospital MCI medical response. Initial search terms included "mass casualty incidents" and "mass casualty or casualties" for the title or abstract. Cited references were also reviewed.

The analysis included articles discussing MCI triage concepts and methods, triage at MCIs, evidence of triage efficacy, and expert perspectives on triage. Articles were excluded when they described MCIs from law enforcement or ethical, psychological, or epidemiological perspectives without detailing the medical response.

Results

Table 1 outlines 28 major MCIs from 1983 to 2020, for a total of more than 37,000 people injured and 4,700 dead, including all incidents discussed in this review, and the triage algorithms used, as reported.

Common Triage Algorithms

Triage algorithms are based on measurements of pulse, mental status, and, usually, respirations. There is not a national standard, nor is there an international standard. (However, this status may change with an effort by the National Highway Safety Administration to promote the Model Uniform Core Criteria for MCI triage.[14]) Following are some of the more common algorithms taught.

Simple triage and rapid treatment (START) is the most widely used triage algorithm in North America (Figure 1).[15–17] The goal is to triage each patient in less than 60 seconds using clinical parameters without specialized equipment or knowledge.[18] START has been used to varying extents at MCIs in the United States.[16,19] Smart triage is a modified START algorithm with emphasis on hemorrhage control for patients with abnormal perfusion or altered mental status.[20,21] JumpSTART, another modified START algorithm, was developed in 1995 for casualties appearing to be under age 8 years (Figure 2).[22,23]

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TABLE 1 *Selected mass-casualty incidents, 1983–2020*

Date	Incident/Site	Type	Location	Est. Victims		Triage Algorithm *(variable use)*
				Injured	Dead	
1983	Beirut barracks	Truck bombing	Beirut, Lebanon	75	305	
1994	Argentine Israelite Mutual Association	Truck bombing	Buenos Aires, Argentina	300+	85	
1995	Alfred Murrah Federal Building	Truck bombing	Oklahoma City, OK, USA	680+	168+	START
1999	Columbine High School	School shooting	Columbine, CO, USA	24	13	*None*
2001	September 11 attacks	Airplane hijackings/crashes	NY/VA/PA, USA	25,000+	2,977	START
2002	Train collision	Train wreck	Orange County, CA, USA	270	2	START
2002	Bali nightclub bombings	Suicide/car bombings	Kuta, Indonesia	209	202	CareFlight
2003	Balochistan train accident	Train wreck	Balochistan, Pakistan	122	8	Triage Sieve
2004	Madrid transport	Bombings	Madrid, Spain	2,000+	191	*None*
2005	London transport	Suicide bombings	London, UK	700+	52	
2007	Virginia Polytechnic Institute & State University (Virginia Tech)	School shooting	Blacksburg, VA, USA	23	32	START
2007	Interstate 35W bridge collapse	Bridge collapse	Minneapolis, MN, USA	145	13	*None*
2009	Turkish Airlines Boeing 737 crash	Airplane crash	Amsterdam, The Netherlands	55	9	Triage Sieve
2009	Fort Hood	Mass shooting	Killeen, TX, USA	32	14	START
2011	Norway attacks	Car bombing, mass shooting	Oslo & Utoya Island, Norway	274	77	*None*
2012	Movie theater	Mass shooting	Aurora, CO, USA	70	12	*None*
2012	Sandy Hook Elementary School	School shooting	Newtown, CT, USA	2	27	
2013	Boston Marathon	Bombing	Boston, MA, USA	264	3	*None*
2014	Fort Hood	Mass shooting	Killeen, TX, USA	14	3	START/ SMART/SALT
2015	Paris attacks	Suicide bombing, mass shooting, hostage crisis	Paris & Saint-Denis, France	352	130+	French natl. system
2015	Inland Regional Center	Mass shooting, attempted bombing	San Bernardino, CA, USA	22	14	*None*
2016	Pulse nightclub	Mass shooting	Orlando, FL, USA	50+	49	START
2017	London Bridge & Borough Market	Vehicle ramming, stabbing	London, UK	48	8	
2017	Route 91 Harvest Music Festival	Mass shooting	Las Vegas, NV, USA	422+	60	None
2017	First Baptist Church	Mass shooting	Sutherland Springs, TX, USA	20	26	
2018	Stoneman Douglas High School	School shooting	Parkland, FL, USA	17	17	
2019	Walmart Store	Mass shooting	El Paso, TX, USA	23	23	
2020	Beirut explosion	Explosion	Beirut, Lebanon	6,000+	204	

The triage sieve algorithm, sometimes referred to as the priority triage system, is used in the United Kingdom and Australia.[11,16–24] It sorts casualties into four categories based on physiologic variables. A modified version developed in 2013 incorporated catastrophic hemorrhage control as the first step (Figure 3).[25] Pediatric triage tape,[16,26] formatted as a portable roll to be unfurled beside pediatric patients, is a system based on triage sieve with height-adjusted physiologic parameters. Part of this triage system makes recommendations for disposition of patients based on their priority; for example, priority 1 patients should be directed to a major trauma center.

In 2001, the four-category CareFlight algorithm, intended for adult and pediatric patients, was developed in Australia (Figure 4).[16,27] Casualties are categorized based on walking, obeying commands, breathing, and radial pulse, without the need for numerical measurements. It was implemented at the 2002 Bali nightclub bombings in Kuta, Indonesia.[16,28]

A mathematical model, the Sacco triage method, was introduced in 2005.[29] The software uses respiratory rate, pulse rate, and motor response to estimate probability of survival. In conjunction with expert consensus data on expected deterioration, this software prioritizes patients in real time.

In 2006, the US Centers for Disease Control and Prevention and the National Association of Emergency Medical Services (EMS) physicians developed a national standard for MCI triage. After reviewing existing algorithms, the Sort, Assess, Lifesaving Interventions, Treatment/Transport algorithm (SALT) was created (Figure 5).[30–32] Patients are sorted into three priority groups based on gross functional ability, followed by assessment, LSIs, and, finally, treatment/transport from highest to lowest priority groups.

The most concise system is Rapid Assessment of Mentation and Pulse (RAMP), which emphasizes two predictors of mortality (Figure 6).[13,33] Following performance of LSIs, triage is based on a casualty's ability to follow commands and the presence of a radial pulse. If only one is present, the patient is triaged as Immediate; when both are present, as Delayed; and when neither is present, as Expectant. A modified RAMP system became standard in Norway after the 2011 attacks there at a summer camp.[13]

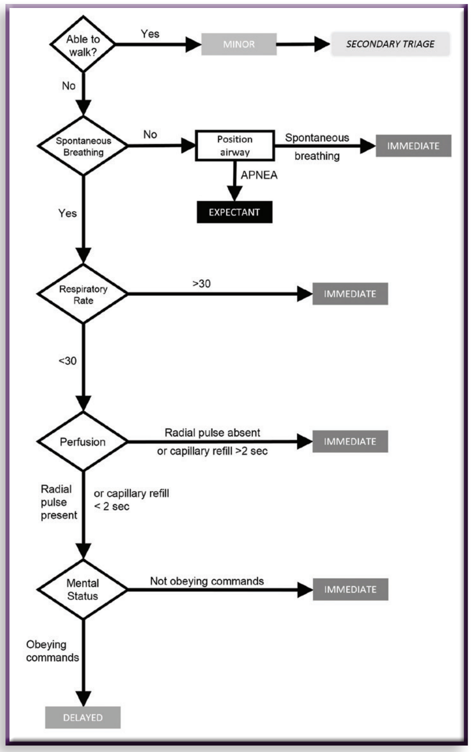
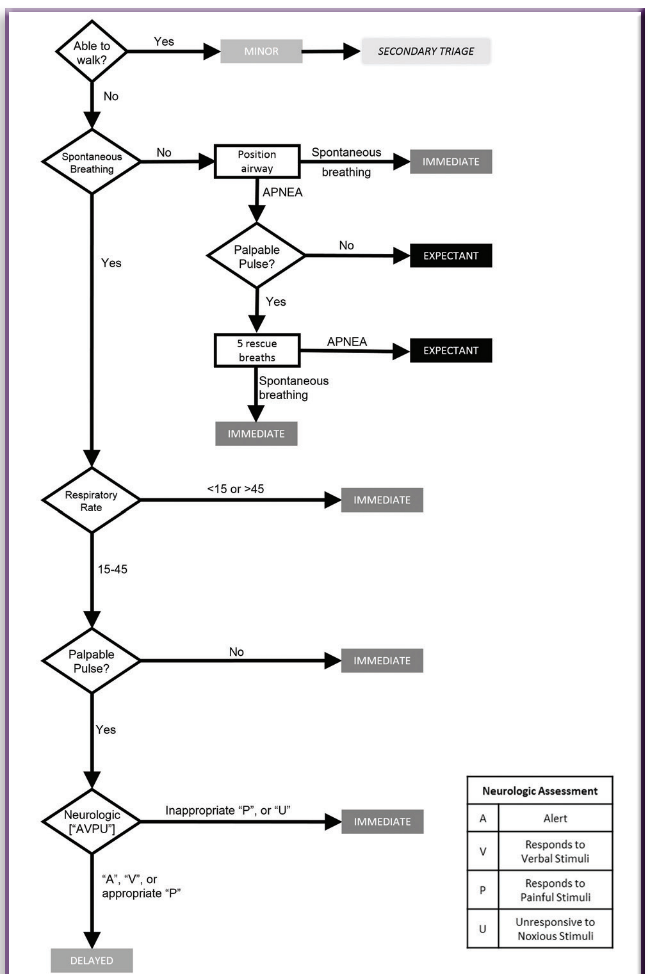


FIGURE 1 *START algorithm.*

Source: U.S. National Library of Medicine

FIGURE 2 *JumpSTART algorithm.*



Source: U.S. National Library of Medicine

FIGURE 3 *"New" triage sieve algorithm.*

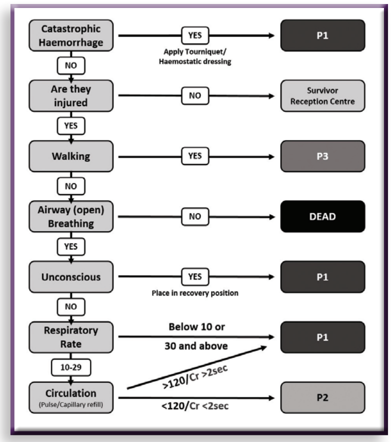


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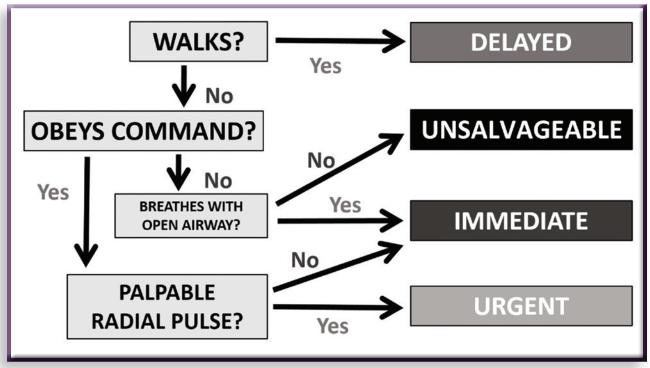
FIGURE 4 *CareFlight algorithm.*



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These systems rely on the use of colored markers to designate casualties based on the triage category; another concept is geographic triage. This groups casualties based on the category without tagging, so that the patients needing immediate advanced care can be taken from one area first (ideally those grouped closest to the transport platform).[34]

Assessments of Triage Systems

There is a paucity of data validating the benefit of triage at sites of actual MCIs. Comprehensive studies have sought to evaluate triage systems and survey provider impressions. Following is an overview of recent evidence on triage efficacy.

Retrospective Studies

A retrospective analysis of multiple triage algorithms found that their ability to predict the need for LSIs in 127,233 trauma registry patients was poor overall.[35] The Modified Physiologic Triage Tool (MPTT) had the highest sensitivity (57.6%) and lowest specificity (71.5%), as well as the lowest rate of under-triage (42.4%) (Table 2). Other algorithms had specificities above 90% but sensitivities below 30%.

Table 3 presents results from a study of the sensitivities and specificities of physiologic parameters and triage algorithms in predicting critical injury.[36] Most of the cited cutoffs demonstrated marginal utility. The Glasgow Coma Scale had the highest sensitivity but is of limited value during an MCI. START, modified START, and CareFlight had high sensitivity and specificity.

A 2013 study compared START, the Fire Department of New York algorithm, CareFlight, Sacco score, and Glasgow Coma

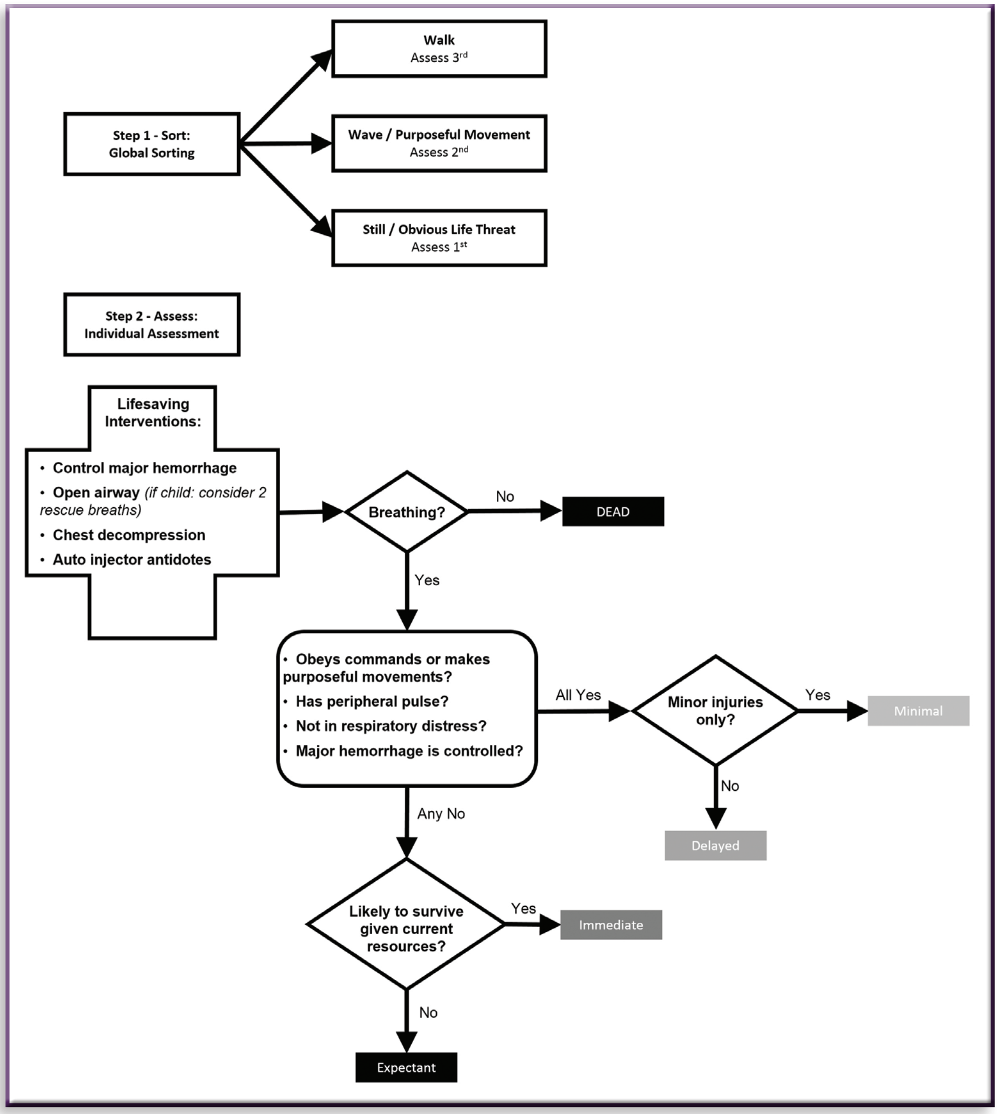
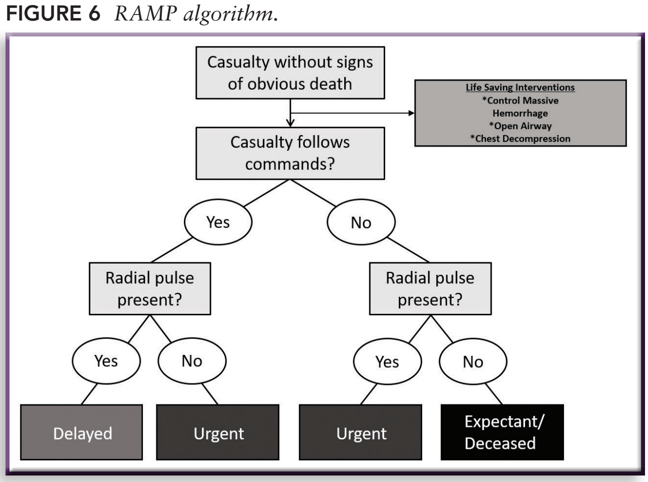


FIGURE 5 *SALT algorithm.*

Source: U.S. National Library of Medicine

FIGURE 6 *RAMP algorithm.*



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Scale in predicting mortality among 530,695 trauma registry patients.[37] No triage method was clearly superior. The Sacco score was most accurate overall but impractical. The survival rate for Expectant patients, which was higher with CareFlight compared with all other triage algorithms (41% vs. 10%), illustrates the critical limitations to these systems.

Prospective Studies

Two prospective studies compared five common triage algorithms applied to emergency department patients with known outcomes (Table 4). Under-triage, correct triage, and over-triage of 125 adults and 115 children were reported for SALT, START/JumpSTART, triage sieve, and CareFlight.[38,39] Under-triage ranged from 26% to 58% in both studies. Triage was accurate for only 36% to 52% of the adult patients and 56% to 59% of the pediatric patients.

Two studies sought to determine the sensitivities and specificities of seven common triage systems in adult and pediatric patients (Table 5).[40,41] Although specificities were high, sensitivities were limited. The Modified Military Sieve performed best among adults, although sensitivity and specificity were relatively low at 68.3% and 79.4%, respectively. Overall, these prospective studies suggest that triage algorithms have limited accuracy and reliability in sorting patients into appropriate triage categories.

Survey Studies

A 2018 survey of EMS clinicians across the United States showed that triage protocols were more likely to be used in training exercises than during actual MCIs.[42] Among responders who participated in both drills and actual MCIs, 91.8%

TABLE 2 *Algorithm sensitivity, specificity, undertriage (1-sensitivity), and overtriage (1-positive predictive value) in predicting LSI need in civilian trauma registry study (% [95% CI]).*

Algorithm	Sensitivity	Specificity	Undertriage	Overtriage
Mod. Phys. Triage Tool	57.6 [56.9-58.2]	71.5 [71.2-71.8]	42.4 [41.8-43.0]	67.1 [66.5-67.7]
Military Sieve	28.0 [27.5-28.6]	94.1 [93.9-94.2]	72.0 [71.4-72.6]	46.7 [56.1-57.3]
Triage Sieve	12.9 [12.5-13.4]	96.7 [96.5-96.8]	87.1 [86.7-87.5]	51.6 [51.0-52.2]
START	28.8 [28.2-29.4]	94.3 [94.2-94.4]	71.2 [70.6-71.8]	45.0 [44.4-45.6]
CareFlight	23.6 [23.1-24.1]	95.9 [95.7-96.0]	76.4 [75.9-76.9]	42.1 [41.5-42.7]

Adapted from Vassallo et al. 2017.29 (Mod. Phys., Modified Physiological.)

reported using triage tags in drills compared with 34.1% reporting usage in actual MCIs. Performing "full triage" was reported in 68.7% in drills and 16.3% in actual MCIs. The most common reason for not using triage tags was the proximity of a hospital (29.5% of respondents). These discrepancies highlight the challenges not captured during training exercises of using triage protocols at actual MCIs.

Triage at Mass Casualty Incidents

Data on triage efficacy during MCIs are limited and difficult to verify. Estimates of over-triage and under-triage at various MCIs, including prehospital and hospital settings, are shown in Table 6.

Mass Casualty Incidents Demonstrating Their Complex Nature Prohibiting Formal Triage

A review of selected real-world events illustrates the chaos and complexity of MCIs.

Boston 2013

At the Boston Marathon bombing, which resulted in approximately 250 casualties, formal use of triage tags was limited. Instead, casualties were evacuated to a casualty collection point, where a general "sweep" triage and LSIs were performed, then loaded into waiting ambulances. This approach cleared the scene of all critical patients within 60 minutes. Interagency and direct field-to-hospital communications also posed a challenge.[43–45]

TABLE 3 *Physiologic variable and algorithm sensitivity and specificity in predicting critical injury in retrospective civilian study (% [95% CI]).*

Variable	Sensitivity	Specificity
RR >29 breaths/min	**14.8**	**95.3**
RR <10 or >29 breaths/min	**25.2**	**95.3**
GCS-Motor Response <6	**72.6**	**96.2**
Systolic BP <80mmHg	**30.4**	**99.2**
Capillary refill >2s	**36.3**	**93.2**
Heart rate >120 beats/min	**33.3**	**91.8**
Algorithm	**Sensitivity**	**Specificity**
START (capillary refill)	**85** [78–90]	**86** [84–88]
Modified START (radial pulse)	**84** [76–89]	**91** [89–93]
Triage Sieve (capillary refill)	**45** [37–54]	**89** [87–91]
Triage Sieve (heart rate)	**45** [37–54]	**88** [86–90]
CareFlight	**82** [75–88]	**96** [94–97]

Adapted from Garner et al. 2001.[21] (RR, respiratory rate; GCS, Glasgow Coma Scale; BP, blood pressure.)

TABLE 4 *Algorithm undertriage, correct triage, and overtriage reported in two prospective Emergency Department studies (% [95% CI])*

	McKee et al. 2020[39] n=125 adults *Reference: criterion standard*			Heffernan et al. 2019[40] n=115 children *Reference: criterion standard*		
Algorithm	**Under**	**Correct**	**Over**	**Under**	**Correct**	**Over**
SALT	**26.4** [18.7–34.1]	**52.0** [43.2–60.8]	**21.6** [14.4–28.8]	**33.0** [24.4–41.6]	**59.1** [50.1–68.1]	**6.1** [1.7–10.5]
START	**56.8** [48.1–65.5]	**36.0** [27.6–44.4]	**7.2** [2.7–11.7]	x	x	x
JumpSTART	x	x	x	**39.1** [30.2–48.1]	**56.5** [47.5–65.6]	**4.3** [0.6–8.1]
Triage Sieve	**57.6** [48.9–66.3]	**36.8** [28.3–45.3]	**6.4** [2.1–10.7]	**39.1** [30.2–48.1]	**55.7** [46.6–64.7]	**5.2** [1.2–9.3]
CareFlight	**57.6** [48.9–66.3]	**36.0** [27.6–44.4]	**5.6** [1.6–9.6]	**39.1** [30.2–48.1]	**55.7** [46.6–64.7]	**5.2** [1.2–9.3]

TABLE 5 *Algorithm sensitivity and specificity reported in two prospective Emergency Department studies (% [95% CI])*

	Vassallo et al. 2014[30] n=335 adults Reference: need for LSI		Wallis et al. 2006[41] n=3,461 Reference: Injury Severity Score >15	
Algorithm	**Sensitivity**	**Specificity**	**Sensitivity**	**Specificity**
START	**51.8** [44.8-58.7]	**89.7** [84.6-94.8]	**31.3** [21.5-42.8]	**77.9** [77.3-78.7]
JumpSTART	x	x	**3.2** [1.3-7.5]	**97.8** [97.7-98]
Triage Sieve	**50.3** [43.3-57.2]	**89.0** [83.7-94.2]	x	x
Pediatric Triage Tape	x	x	**37.8** [32.7-42.5]	**98.6** [98.3-98.8]
CareFlight	**44.7** [37.8-51.6]	**91.9** [87.3-96.5]	**48.4** [43.4-52.8]	**98.8** [98.6-99.1]
Military Sieve	**63.3** [56.6-70.0]	**82.4** [75.9-88.8]	x	x
Modified Military Sieve	**68.3** [61.9-74.8]	**79.4** [72.6-86.2]	x	x

TABLE 6 *Selected overtriage and undertriage rates (%) at MCIs, as reported*

Incident	Overtriage	Undertriage
Beirut 1983[63]	80	0
Buenos Aires 1994[9,64,65]	56	x
Oklahoma City 1995[9] (START)	37	x
New York City 2001[65,66] (START)	70	x
Madrid 2004[65,68]	89	0
London 2005[65]	64	x
Virginia Tech 2007[69,70]	69	10
Amsterdam 2009[22] (Triage Sieve tags in 12%)	80	11

Paris 2015

The 2015 attacks in Paris resulted in 130 deaths and 495 live casualties. Triage and management were systematic and led by tactical physicians. Similar to lessons learned at other events, the Paris attacks demonstrated that a system to provide adequate numbers of hemorrhage-control devices is necessary to improve MCI care.[2,13,46,47]

San Bernardino 2015

The 2015 San Bernardino shooting resulted in 36 casualties. Improvised extrication using blankets and chairs illustrated the importance of training on casualty movement skills. Though trained to use START/JumpSTART, responders instead "reacted" using clinical judgement. Triage tags were not widely used, but critical patients were transported within an hour. Overall, this incident demonstrated an intuitive response, but the number of injured was substantially more manageable than at other MCIs.[13,48–50]

Las Vegas 2017

The outdoor festival shooting in 2017 on the Las Vegas strip resulted in 58 dead and 527 injured. It is another example of an overwhelming MCI. Bystanders transported casualties in personal vehicles. There was no substantive casualty collection point or triaging until casualties reached hospitals, which were overwhelmed and unaware of the volume of incoming patients. There was a lack of coordination and communication among responders, law enforcement, and hospital personnel.[51,52]

Movement of Casualties at MCIs

Although no studies specifically address the movement of casualties during these incidents, it is mentioned in some real-world events.[13,43–52] It was also observed by the senior authors who ran these exercises that this part-task skill should be emphasized in training. Moving casualties off the incident site generally requires improvised techniques. These should be codified and rehearsed.

Discussion

This literature review showed that triage systems are relatively inaccurate and infrequently used. The events referenced demonstrate the variable use of triage algorithms. Their use is limited by chaos, mortal danger, and low adoption by EMS providers. Overall, the results of this analysis, similar to the conclusions of Vayer et al[34] in 1986, suggest the need to further simplify the triage process. Other authors have identified gaps in training and preparedness and recommend prioritizing scene safety, undertaking rapid triage and transport, providing limited on-scene care, and optimizing LSI timing.[53–57]

The data summarized above do not show a clear benefit of using any algorithm. They are inaccurate and too complicated to memorize from occasional training. In fact, some authors suggest that the experience and judgment of EMS clinicians play a substantial role during MCIs and may be as effective as formalized algorithms.[13,54,58,59] Therefore, it may be prudent to have the most experienced clinician on site act as the triage officer.

Longstanding efforts have sought to identify the ideal parameters on which to base triage decisions. The use of physiologic parameters derived from retrospective analyses has shown the highest sensitivity among various triage algorithms.[60,61] However, they are difficult to obtain on-scene, delay action, and are potentially unreliable.[13] All algorithms are variations on daily practice: taking the radial pulse, ability to follow commands, and often, measurement of respirations. For now, they should be the basis for triage, but perhaps without a formal algorithm to memorize.[62–64]

Evidence on the optimal number of triage categories for MCIs remains limited. The most widely used algorithms assign patients into four categories: Immediate, Delayed, Minor, and Expectant/Deceased. The Las Vegas fire department used three categories: Walking wounded, Litter, and Expectant.[65,66] Whereas some authors recommend simplifying categories to as few as two (i.e., "seriously injured" and "walking wounded"),[9] others recommend as many as five categories, suggesting that an optimal number is unknown.[67] We support the use of a simplified, three-category system with geographic grouping: transport now, transport later, deceased.

LSIs should be used when indicated. Recent military and civilian experience supports not waiting until after triage to stop massive bleeding, in agreement with prior algorithms.[13,48,55,56,62,68]

Efficient patient movement from the scene to a collection area or medical facilities is problematic and complicated by patient access,[52] environmental factors,[13] lack of stretchers,[13,46] and uncertainty over the role of non-EMS vehicles.[50,52] Recent anecdotal reports have credited bystanders and law enforcement personnel for providing early LSIs and transport prior to EMS arrival.[52] The use of non-EMS personnel and vehicles should be included in MCI plans.[55]

Although there is not a uniform standard triage system, an attempt has been made by the US Department of Transportation National Highway Safety Administration to use the Model Uniform Core Criteria for MCI triage,[14] even though it, too, contains many of the issues identified in this review.

In general, we concur with the recommendations of Vayer et al,[34] who suggest simplifying triage as much as possible. They advocate for using common daily practices as opposed to new systems with unique terminology. Finally, they support a more intuitive triage system, grouping casualties together based on severity, without using tags or complex labeling systems.

Limitations

Given the chaotic and dangerous nature of MCIs, data collection to study these events is inherently limited by retrospective data collection, partly based on recall. It is virtually impossible to collect data prospectively unless someone is assigned to do this in advance or, ultimately, if technology is used on all casualties. Comparing triage methods, other than in tabletop exercises or studies, is even more difficult given the frequency and wide variability of real-world events.

Conclusion

Many MCI algorithms exist. They use measurement of pulse, mental status, and respirations to sort the severity of casualties and among them have four or five categories requiring the placement of tags. Most treatment is limited to bleeding control. Common failure points in MCIs include communications and movement of casualties. Overall, triage systems are infrequently used and have limited efficacy. MCIs are chaotic and dangerous and can involve dozens to hundreds of casualties in varied and complex environments. Adoption of simpler, more easily reproduced systems may improve first responder use of such algorithms.

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