Evaluation of Pediatric Trauma Triage Criteria for Highest Activation

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Information /Qualifications: Principal and Co-Investigators

All investigators are members of Trauma Services within the Division of Pediatric and Thoracic Surgery at Cincinnati Children's Hospital Medical Center.

The principal investigator, **Richard A. Falcone, Jr., M.D., M.P.H.,** is the Director Trauma Service at Cincinnati Children's Hospital. His extensive knowledge and experience in pediatric trauma management, along with Dr. Falcone's Masters of Public Health from Harvard University specializing in Outcomes Research, provides a strong foundation for development of quality research studies.

Lynn Haas RN, MSN, CNP has been the Trauma Program Manager at Cincinnati Children's Hospital for the past 21 years. Ms. Haas has extensive experience as a pediatric trauma program manager and has been involved in numerous performance improvement initiatives and clinical research projects.

Suzanne Moody, MPA is the Research Coordinator at Cincinnati Children's for the past year. Her previous experience includes trauma project management at the Greater Cincinnati Health Council.

Margie Koehn, **CSTR**, has had oversight over the trauma registry at Cincinnati Children's for the past 18 years and is a recognized expert in trauma data management. Ms. Koehn is a member of the Ohio Trauma Registry Advisory Subcommittee (TRAS) and past president of the Ohio Alliance of Trauma Registrars (AOTR). Her expertise assisted in the development of the web-based database and exporting of data.

Taunya Kessler, CCS is the current Trauma Registrar at Cincinnati Children's and has extensive knowledge in coding and quality monitoring of registry data. Ms. Kessler is the current vice-president of the AOTR and a member of the Tri-State Trauma Coalition (TSTC) Performance Improvement Committee.

Executive Summary

The goal of this study was to prospectively evaluate the correlation of triage criteria, including those mandated by the ACS, with the need for immediate resources provided by a trauma resuscitation team. Two consensus lists were developed: 1) pre-hospital activation criteria and 2) Emergency Department (ED) high level resources requiring full team trauma activation. Inclusion criteria included any traumatically injured child evaluated by the Trauma Service in the ED who met either an activation criterion or used a specific resource. Drowning and suffocation victims were excluded.

A total of 656 patients were entered into this study from 9 verified Level I / II pediatric trauma centers over a one-year study period. Forty-five percent (N=296) of the patients utilized at least one high level resource. Gun-shot to the abdomen (92%), blood given prior to arrival (83%), traumatic arrest (83%) and tachycardia with poor perfusion (83%) were most predictive of utilizing a high level resource at least once. Definitions of appropriate triage (i.e. criteria with ED resource use), over-triage (i.e. criteria without ED resource use) and under-triage (i.e. no criteria with ED resource use) were developed and were the basis for the study conclusions. Of the 656 enrolled patients, 55% would have been over-triaged while 9% would have been under-triaged.

All activation criteria were ordered in priority according to the percentage of time a resource was utilized. Over-triage and under-triage were re-calculated with the sequential addition of one criterion. After the addition of the 9th criteria, there is a point where the addition of more criteria only increases the over-triage rate but has minimal impact on the under-triage rate. The six mandated ACS COT criteria (ACS-6) were evaluated for effectiveness. Within the study population, 350 (53%) patients met at least one ACS-6 criteria. Utilizing the ACS-6, 24% would have been over-triaged and 16% would have been under-triaged. It is significant that the under-triage is only 16% with the use of 6 criteria but only decreases to 9% with the presence of all 23 criteria. Overall, the ACS-6 performed well in the context of over-triage and under-triage rates. The inclusion of additional criteria had little impact on under-triage but instead, continued to increase the over-triage rate.

On specific analysis, five of the 6 ACS-6 criteria were consistently listed within the top 10 criteria within the ranking system that was utilized for this study. Only "GCS deterioration by 2" was consistently ranked lower than the other 5. With the deletion of the "GCS deterioration by 2" criterion, the addition of "tachycardia / poor perfusion" and "40 ml / kg bolus prior to arrival" (i.e. ACS-7) could potentially limit resource utilization for pediatric trauma resuscitations while continuing to maintain the acceptable over-triage and under-triage rates.

In conclusion, highly sensitive pediatric triage criteria are needed in order to appropriately initiate the highest level of trauma team activation. The ACS-6 mandated criteria performed well when evaluating this by over-triage and under-triage rates of the highest injured pediatric patients. It is generally accepted that some amount of over-triage is necessary to minimize the risk of under-triage. The inclusion of additional criteria beyond the ACS-6 had a small impact on under-triage yet continued to increase the over-triage rate significantly. Small revisions in the ACS-6 criteria for the pediatric population may potentially have some benefits.

Introduction

Verified trauma centers utilize the trauma resuscitation team concept to provide immediate care to the severely injured patient. The size and composition of a resuscitation team vary per hospital with some basic mandated components. In order to increase efficiency, most trauma centers utilize a tiered trauma resuscitation system, matching the personnel and resources of the resuscitation team to the immediacy of the patient's need for care. In many hospitals across the nation, a three-tiered system exists - highest level of activation for the most critical, mid-level activation for moderate injuries, and lowest tier evaluation for those with more minor injuries. Resources vary at each level, increasing as the level of activation increases.

The goal of distributing scarce resources in a safe and cost-effective manner is achieved through appropriate triage criteria for each tier of the trauma resuscitation. In May 2002, the Committee on Trauma of the American College of Surgeons (ACS COT) mandated 6 triage criteria for the highest level of activation for both adult and pediatric trauma centers.[1] Trauma centers were then encouraged to expand their triage criteria, eventually leading to each hospital developing their own unique grouping of activation criteria. A variety of triage criteria have been proposed and adopted, but a national consensus does not exist for the highest level of activation. The goal of this study was to prospectively evaluate the correlation of triage criteria, including those mandated by the ACS, with the need for immediate resources provided by a trauma resuscitation team. As resource utilization and acuity are highest for the most critically injured child, the findings of this study take an important first step toward improving the quality and timeliness of care in a fiscally responsible manner.

Review of Literature

It is estimated that 10-15% of traumatically injured children have life threatening injuries that demand a rapid and systematic approach to their treatment.[2] Even more significant is that the presence of a trauma resuscitation team can decrease mortality by 25% to 30% for the seriously injured child. [2]

With this knowledge, it remains imperative that accurate field and hospital pediatric triage criteria are defined and utilized for the highest level of trauma resuscitation activation.

Over the past decade, the benefits of tiered trauma resuscitation have included improved staff utilization and reduced costs while maintaining favorable outcomes in the area of safety, morbidity, and mortality.[3-15] Even with this positive clinical benefit, trauma clinicians quickly realized that the presence of a trauma resuscitation team in the Emergency Department consumed many hospital resources. In 2002, the ACS COT delineated six minimum triage criteria (ACS-6) for the initiation of adult / pediatric highest activation trauma resuscitations.[1] These include the following:

- age-specific hypotension
- respiratory compromise or obstruction
- transfer patients from another hospital who are receiving blood
- gunshot wound to the abdomen, neck or chest
- Glasgow Coma Scale (GCS) score of ≤ 8
- deterioration of Glasgow Coma Scale score by 2

In 2006, the ACS COT updated their publication "Resources for Optimal Care of the Injured Patient" to include these 6 triage criteria as requirements, along with the presence of key individuals and physician response time for highest level trauma activations.[1] After meeting these basic requirements, each trauma hospital can expand beyond these criteria to fit its needs. However, along with this freedom comes inconsistency, as each hospital has different triage criteria for the highest level of trauma team activation.

Trauma researchers now suggest that some common trauma triage criteria, currently utilized across the nation, can be eliminated so as to substantially decrease over-triage, or false positive results, without increasing under-triage, or false negatives results.[14, 16] More specifically, over-triage refers to unnecessary mobilization of a trauma resuscitation team for patients without significant injuries. When over-triage occurs, this leads to increased stress on resources and inefficiency. Conversely, under-triage refers to not mobilizing adequate resources available to treat an injured child. Under-triage affects the overall safety of the injured child as life-threatening injuries can initially go undetected, possibly leading

to a negative outcome. It is generally accepted that some amount of over-triage is necessary and expected in order to minimize the risk of under-triage.

In order to minimize both over and under triage it is crucial to carefully exam triage criteria for their effectiveness. Mechanism of injury in isolation as a criterion has not been found to be indicative of the need for a resuscitation team.[6, 11, 12, 17-25] The only specific mechanism of injury that does yield a high sensitivity as a criterion is a gun-shot wound to the torso or head.[12, 19, 24-26] Combining parameters and adding a scoring system has demonstrated high sensitivity / specificity yet has proven to be cumbersome to complete during a critical and stressful situation.[14, 16, 22, 27-30]

Recent studies indicate that physiologic parameters are strong indicators for when to activate the highest activation within a tiered system.[12, 14, 19, 30, 31] Examples of such physiologic parameters include respiratory rate [31, 32], intubation status [31, 33], Glasgow Coma Score (GCS) [12, 14, 17, 31, 34, 35], heart rate [36-38], and systolic blood pressure [13, 20, 31, 33, 39], each of which has its own limitations. Most of these studies have been completed in the adult population, with only a few being pediatric specific.[22, 40, 41]

A study completed by Steele et al. did not support the obligatory use of the six required ACS COT criteria, either for adults or pediatrics patients; [42] however, these criteria continue to be mandated for adult and pediatric trauma centers. Additional difficulty exists as many individuals question the use of adult triage criteria for children. A study by Phillips et al. concluded that utilization of adult triage criteria for children leads to high under-triage rates.[40] Conversely, unnecessary over-triage has the potential to divert time and resources away from other sick children in the Emergency Department. Therefore, in order to provide optimal care, it is extremely important to develop highly sensitive triage criteria to ensure all pediatric trauma patients who require expeditious trauma care receive it with maximum efficiency, given the type and severity of the injury.

Methodology

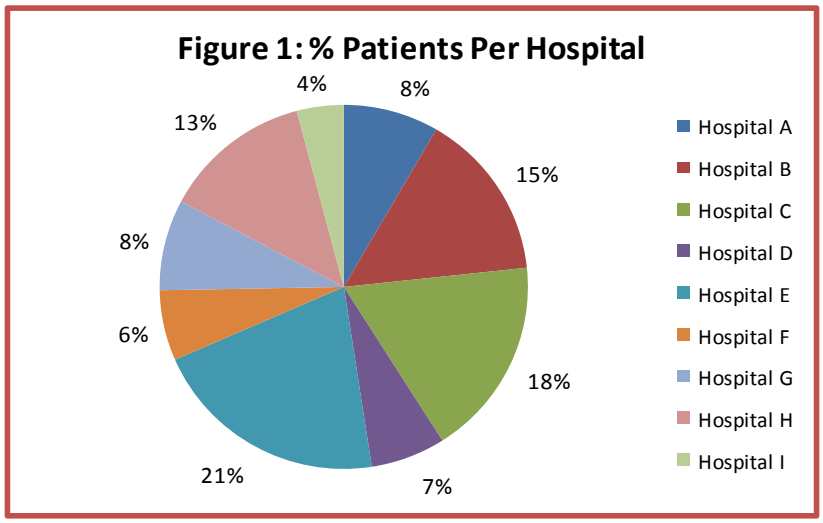
This prospective multi-center observational study involved the following nine verified Level I / II pediatric trauma centers: Cincinnati Children's Hospital, Akron Children's Hospital, Children's

Hospital of Pittsburgh, Children's Hospital of Wisconsin, Dayton Children's Hospital, Dell Children's Medical Center of Central Texas, Nationwide Children's Hospital, Rainbow Children's Hospital, and Toledo Children's Hospital. The study was approved by the Institutional Review Board (IRB) of each participating hospital.

Highest activation trauma triage criteria from participating pediatric trauma centers were aggregated and grouped by criteria. Standardization of criteria was required for the following: 1) degree of body surface area for burns with exclusion of location; 2) location of amputation and decision to exclude digit amputations; 3) inclusion of paralysis and / or motor deficit within the suspected spinal cord injury category; and 4) decision regarding age appropriate blood pressure limits. A Delphi method of reaching consensus was then utilized, obtaining expert opinions from all Ohio pediatric Trauma Directors and Trauma Program Managers. The initial list, which contained 34 criteria, was distributed to all members who then ranked each activation criteria from highest to lowest priority. After the first round of voting, the following 4 low priority criteria were subsequently eliminated: positive loss of consciousness (LOC), high voltage electrical contact, confirmed intracranial bleed with GCS ≤ 12, and LOC with GCS ≤ 12. Scores were reviewed and then re-ranked by the expert consensus panel. After the second round of voting, the criterion of "witnessed pedestrian run over" was also eliminated, taking the final consensus list to 29 criteria. **(Appendix 1 – hereinafter designated as "Criteria")** Interestingly, discussion occurred regarding eliminating the lowest two criteria – "death of a same vehicle occupant" and "ejection from vehicle". However, as these criteria were thought to occur frequently on a national level, it was decided to include them within the study and analysis.

As with the activation criteria, a Delphi method of prioritization was utilized for development of a consensus list of Emergency Department (ED) procedures that the panel of experts believed should correlate with the highest trauma team activation. An initial list of 14 procedures was generated and standardized. After two rounds of prioritization, emergency tracheostomy and emergent transfer to PICU were eliminated from the procedure list. Based on the second review, a final list of 12 ED procedures was generated. **(Appendix 2 – hereinafter designated as "Resource")**

For inclusion in this study, traumatically injured children evaluated by the Trauma Service at an American College of Surgeon's or state verified pediatric trauma center were screened. Only those patients that met any criteria in **Appendix 1** <u>or</u> **Appendix 2** and were evaluated in the Emergency Department were included in the study. Children who were pronounced dead in the Emergency Department due to a traumatic injury were included, while children who were victims of drowning and suffocation were excluded from the study.



Once patient eligibility was established, data was collected from all nine pediatric trauma centers and entered into a password protected on-line data collection program. Study patients were able to meet multiple activation criteria and utilize multiple resources. Additional demographic information and specific clinical outcomes were obtained from each hospital's Trauma Registry**.**

Statistical analysis was performed for the continuous variables (i.e. age, ISS, time to OR transfer and time to ICU transfer) using the Wilcoxon Rank Sum test. For the categorical variables (i.e. mortality, ED disposition, and discharge to rehab) the two groups were compared using the Fisher's Exact test. All tests were conducted at the two-sided 5% level of significance.

<u>Analysis of Research Findings</u>

Patient Characteristics

A total of 656 patients were entered into this study from 9 verified Level I / II pediatric trauma centers over a one-year study period. Percentage of patients per hospital varied from 4% - 21%. (Figure 1) In order to assess for hospital bias, the percentage of study patients to overall admitted injured patients was calculated. (Table 1)

Table 1: Patient Volume from Participating Hospitals

	Level of Pediatric Verification	# Patients in Study	# Trauma Registry Patients during Study Period	% of Total Patients Entered in Study
Hospital A	II	55	1285	4.3%
Hospital B	I	98	1185	8.3%
Hospital C	I	116	1719	6.7%
Hospital D	I	43	430	10.0%
Hospital E	I	137	1982	6.9%
Hospital F	II	41	614	6.7%
Hospital G	I	53	714	7.4%
Hospital H	I	86	1416	6.1%
Hospital I	I	27	377	7.2%
TOTAL		656		Avg = 7.1

The average percentage of injured pediatric patients admitted to the study was 7.1% with a range between 4.3% - 10.0% for the nine participating hospitals. As to be expected, hospitals with larger overall injured patients submitted more patients to the study; however, percentages were fairly consistent.

Of these 656 patients, 72 died (11%), with 24 patients (4%) dying during resuscitative measures in the Emergency Department (ED). Median age was 8.1 years with a median ISS of 14.0. The most frequent ED Disposition was PICU (43%); however, a significant population (22%) went directly from the ED to the Operating Room (OR). Seventy four patients (11%) ultimately required an in-patient rehabilitation admission. (Table 2)

Table 2: Demographic Information on Study Population

	N	Mean	Median		N	%
Age	656		8.1	**Mechanism of Injury**		
ISS	656		14.0	MV-occupant	153	23.3
Time to OR (min)	147		74.6	Falls	88	13.4
Time to ICU (min)	284		92.7	NAT / abuse	66	10.1
	N	%		Struck by/against	63	9.6
Activation Status				MV-pedestrian	39	6.0
Highest	405	61.7		Gun-shot	33	5.0

Mid	162	24.7		BB	29	4.4
None	89	13.6		Sports	21	3.2
	N	%		Bike	16	2.4
ED Disposition				Fire/flames	13	2.0
PICU	284	43.3		MV-bike	13	2.0
Floor	154	23.5		Other	122	18.6
OR	147	22.4			N	%
Morgue	24	3.7		Mortality	72	11.0
Other	47	7.2		D/C to Rehab	74	11.3

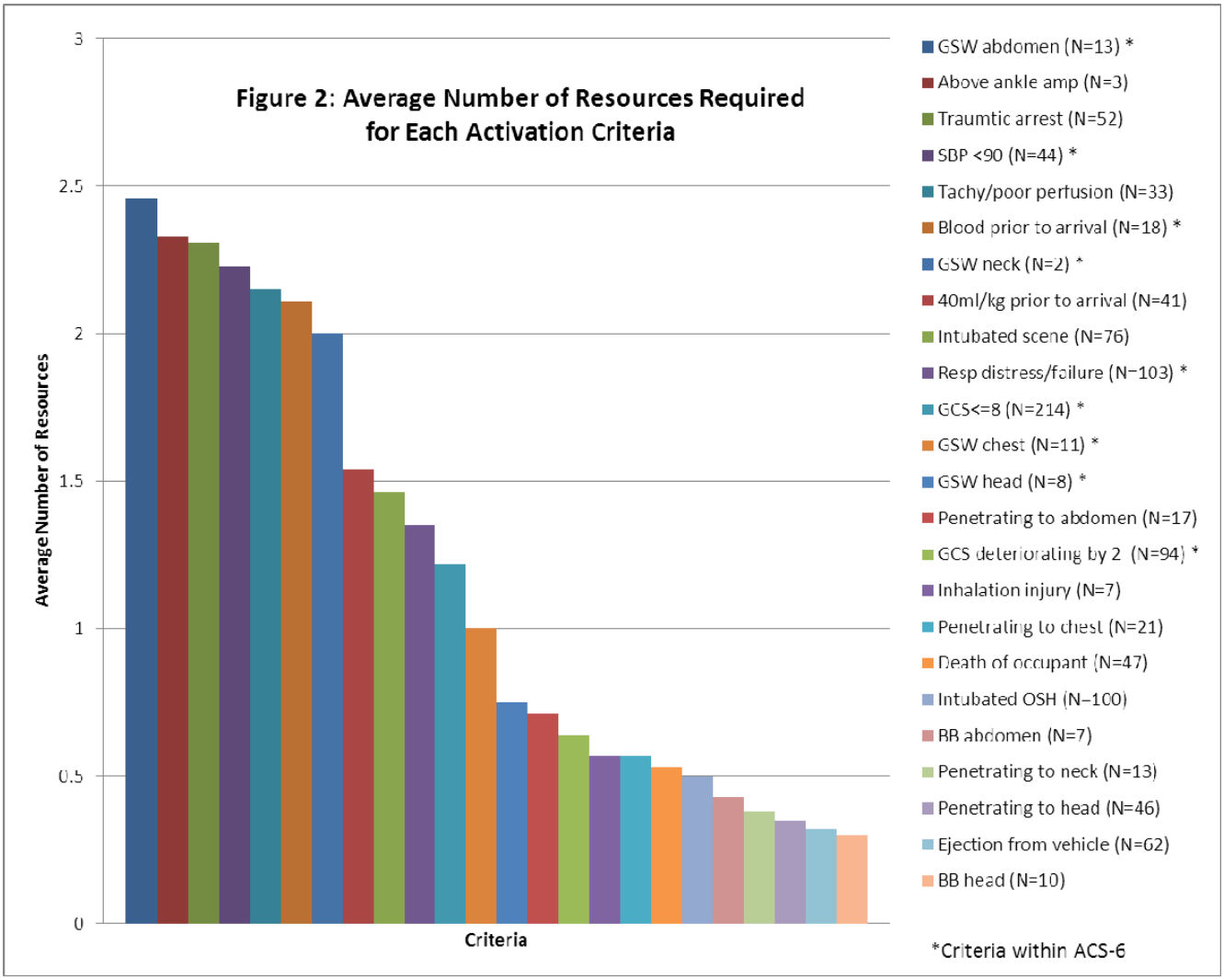
Of the 656 patients, 596 (91%) met at least one triage criterion, while 255 (43%) met 2 criteria and 119 (20%) met three or more criteria. The most common criterion was GCS ≤ 8 (N=214), followed by respiratory distress (N=103), intubated at outside hospital, (N=100) and penetrating non gun-shot (N=97). Of the 656 patients, 296 (45%) utilized at least one high level resource (range 1-7) during the ED resuscitation. Of those patients that required a resource, 202 (68%) used 1 resource, 70 (24%) used 2-3 resources while 24 patients (8%) used 4-7 resources. The most frequent ED resource utilized was intubation / re-intubation (N=115), blood administration (N=67), and ≥ 40 ml / kg fluid bolus after patient arrival (N=63). The resource procedure of pericardiocentesis was not utilized for any patients in this study. (Table 3)

Table 3: Frequency of High Level ED Resources

Resources	# of Occurrences	Frequency
Intubation / Re-intubation	115	17.5%
Blood administration	67	9.9%
Fluid bolus: ≥ 40 /kg after arrival	63	9.6%
Time to OR: 45 – 90 min after arrival	62	9.5%
Time to OR: < 45 min after arrival	50	7.6%
CPR	38	5.8%
Central line	32	4.9%

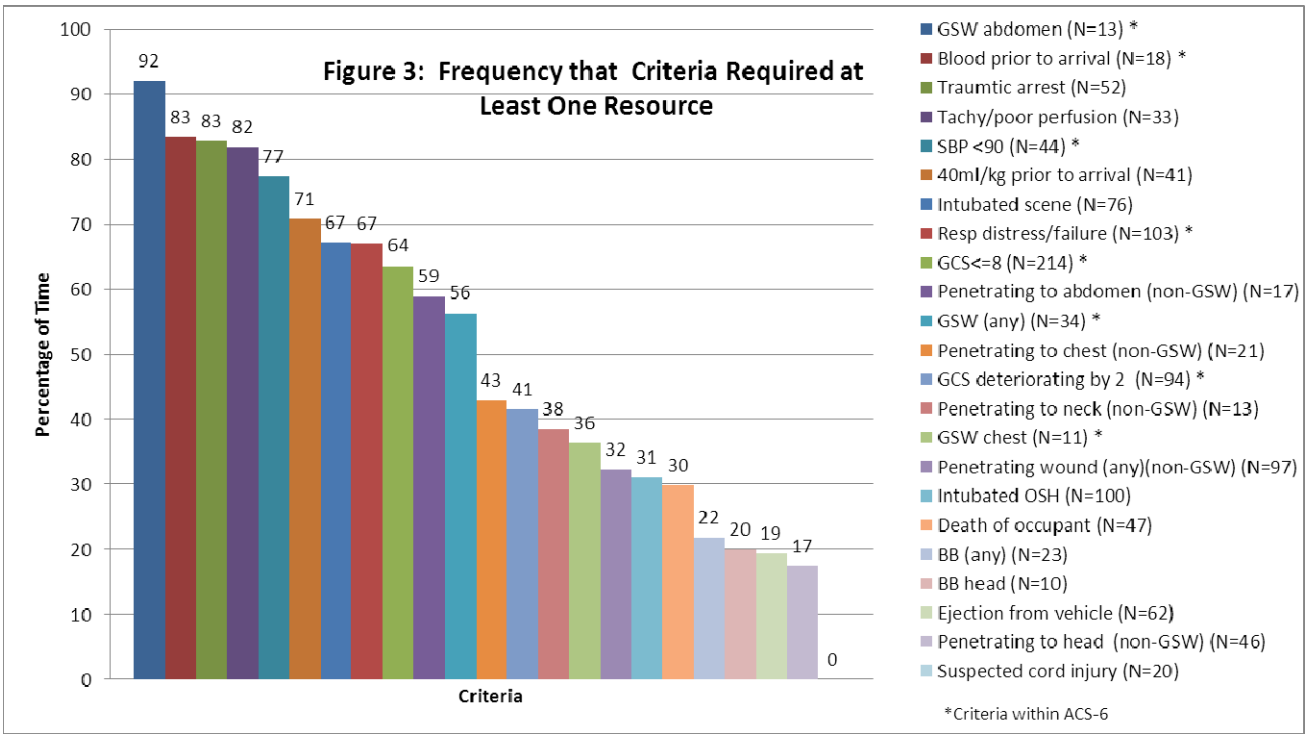
IO insertion	22	3.4%
Chest tube insertion	21	3.2%
Needle decompression	6	0.9%
Open thoracotomy	3	0.5%

For each criterion, the average number of resource utilization was calculated. The criterion of gun-shot to the abdomen utilized the most resources with an average of 2.46 resources per occurrence, followed by above-the-ankle amputation (2.33 resources), and traumatic arrest (2.31 resources). Seven activation criteria averaged more than 2 resources while an additional 5 criteria averaged at least 1 resource per occurrence. (Figure 2)

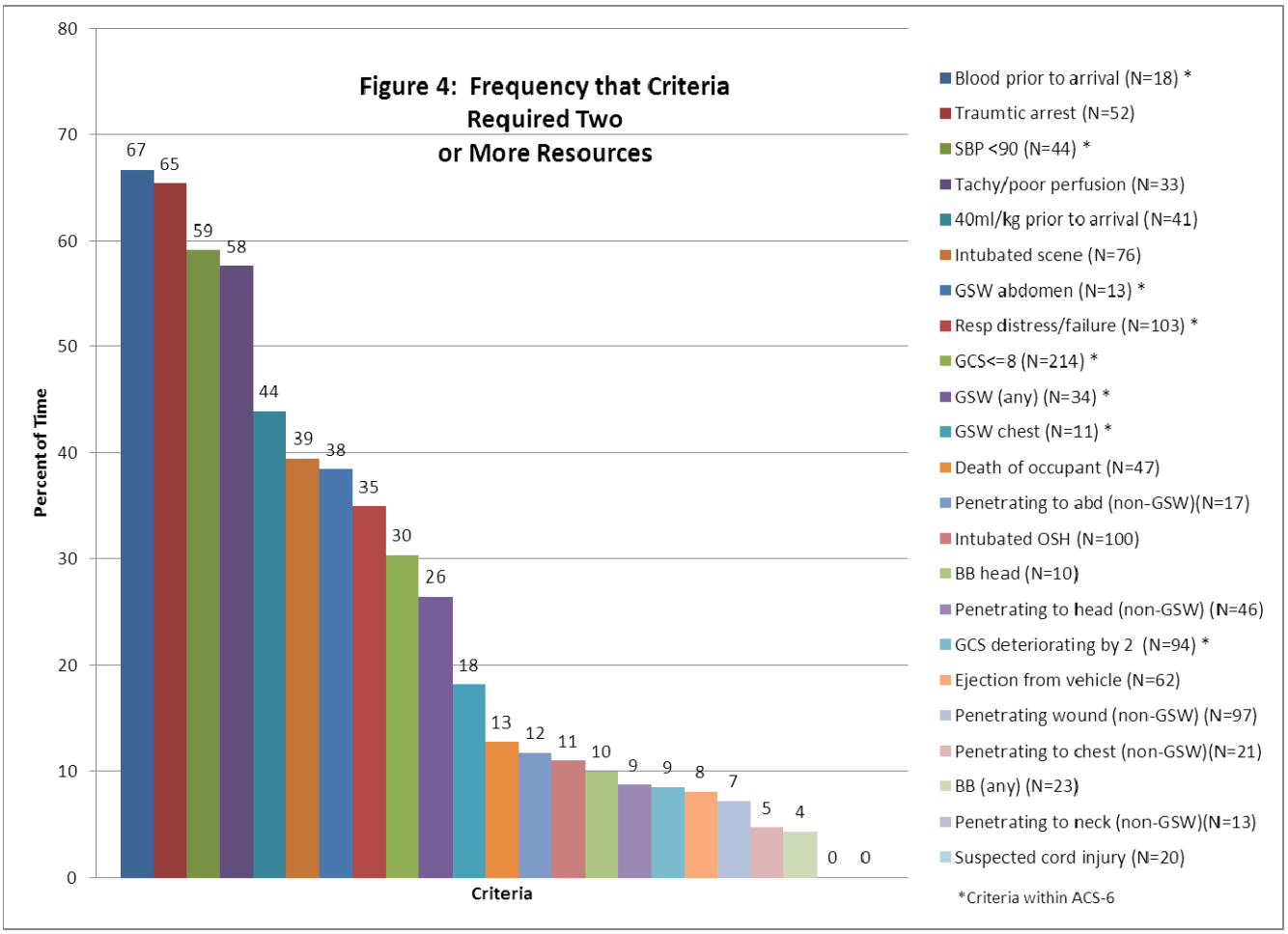


In this study population, there were certain activation criteria which occurred infrequently. These small sample sizes limited the validity of study conclusions related to these criteria. Therefore, criteria which contained less than 5 patients, such as above wrist amputation (N=0) and above ankle amputations (N=3), were excluded from further analysis. BB chest (N=4), BB neck (N=2), and gun-shot neck (N=2) were either grouped within the "BB any" or "GSW any" category.

Among criteria with more than 5 patients, gun-shot to the abdomen (92%), blood given prior to arrival (83%), traumatic arrest (83%), and tachycardia with poor perfusion (83%) were most predictive of utilizing a high level resource at least once. Eleven of the 23 criteria required at least 1 resource 50% of the time. Twenty patients with suspected spinal cord injury did not use a high level ED resource in any circumstance. (Figure 3)



The most frequent activation criteria that required two or more resources was blood prior to arrival (67%), followed by traumatic arrest (65%), age appropriate SBP < 90 (59%), and tachycardia with poor perfusion (59%). Overall, the top 11 activation criteria were consistent in both the single resource and the two or more resource category. (Figure 4)



Over-Triage and Under-triage: Relationship of Activation Criteria with Resource Utilization

Central to conclusions for this study is the methodology of measuring: 1) appropriate triage; 2) over-triage; and 3) under-triage. The definitions related to this study for over-triage and under-triage are specific only to high level trauma activations. Table 4 depicts how this study defines over-triage and under-triage in the context of the highest trauma activation criteria utilized and the overall study inclusion numbers within each category. Utilizing this matrix for all 656 enrolled patients, 55% (360/656) would have been over-triaged while 9% (60/656) would have been under-triaged

Table 4: Relationship of Resource Utilization vs. Activation Criteria

		Resource Utilization	
		No	**Yes**
Activation Criteria	**No**	(Not in study)	**Under-triage** = no activation criteria but yes resource N=60
	Yes	**Over-triage** = activation criteria met but no resource N=360	**Appropriate triage** = activation criteria met and yes resource N=236

For each of the 23 activation criterion with more than 5 patients, the following measures were calculated: 1) over-triage, 2) under-triage, and 3) percent of time a resource was utilized. Criteria were then ordered in priority according to the percent of time that a resource was utilized. Over-triage and under-triage were re-calculated with the sequential addition of one criterion. Using this information, the following figure depicts the relationship of over-triage and under-triage utilizing the sequential addition of criteria. (Table 5)

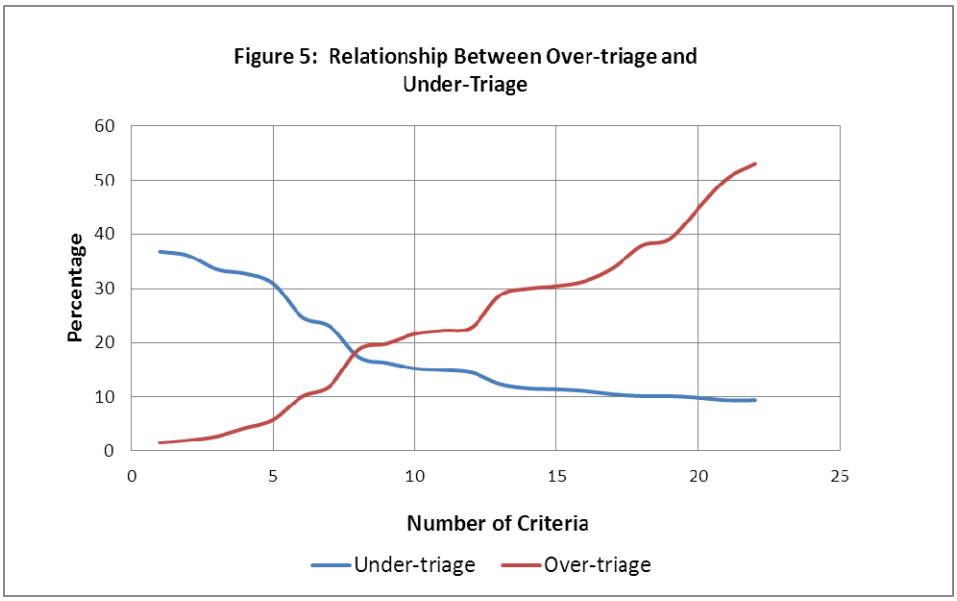
Table 5: Sequential Listing of Criteria with Over-Triage and Under-Triage

Sequential Addition of Criteria	**Criteria (Ordered by: % Time Any Resource Utilized)**	**Under-triage**	**Over-triage**	**% Time Resource Utilized When Criteria Present**
1	Gunshot abdomen (N=13)*	43.29	0.15	92
1-2	Traumatic arrest (N=52)	36.89	1.54	83
1-3	Blood prior to arrival (N=18)*	36.13	1.99	83
1-4	Tachy/poor perfusion (N=33)	33.54	2.74	82
1-5	SBP <90 (N=44) *	32.77	4.27	77
1-6	40ml/kg prior to arrival (N=41)	30.95	5.79	71
1-7	Resp distress/failure (N=103) *	24.85	10.06	67
1-8	Intubated scene (N=76)	23.02	12.04	67
1-9	GCS<=8 (N=214)*	17.38	18.75	64
1-10	Penetrating abdomen (non-GSW)(N=17)	16.31	19.82	59
1-11	Penetrating to chest (no-GSW) (N=21)	15.24	21.65	43
1-12	Inhalation injury (N=7)	14.94	22.26	43
1-13	BB abdomen (N=7)	14.48	22.87	43
1-14	GCS deteriorating by 2 (N=94)*	12.35	28.81	41
1-15	Penetrating to neck (non-GSW) (N=13)	11.59	30.03	38

1-16	GSW head (N=8)*	11.43	30.49	38
1-17	GSW chest (N=11)*	11.13	31.4	36
1-18	Intubated OSH (N=100)	10.52	33.84	31
1-19	Death of occupant (N=47)	10.21	37.96	30
1-20	BB head (N=10)	10.21	39.18	20
1-21	Ejection from vehicle (N=62)	9.91	44.82	19
1-22	Penetrating to head (non-GSW) (N=46)	9.45	50.3	17
1-23	Suspected cord injury (N=20)	9.45	53.05	0

*Criteria within ACS-6

An inverse relationship exists, for when the under-triage decreases; there is a concomitant increase in over-triage. (Figure 5) After the addition of the 9th criteria, the under-triage slope starts to lessen and after the addition of the 15th criteria, the under-triage curve appears to flatten out. At this point, there may be a point of diminishing return, where the addition of more criteria only increases the over-triage rate but has minimal impact on the under-triage rate.



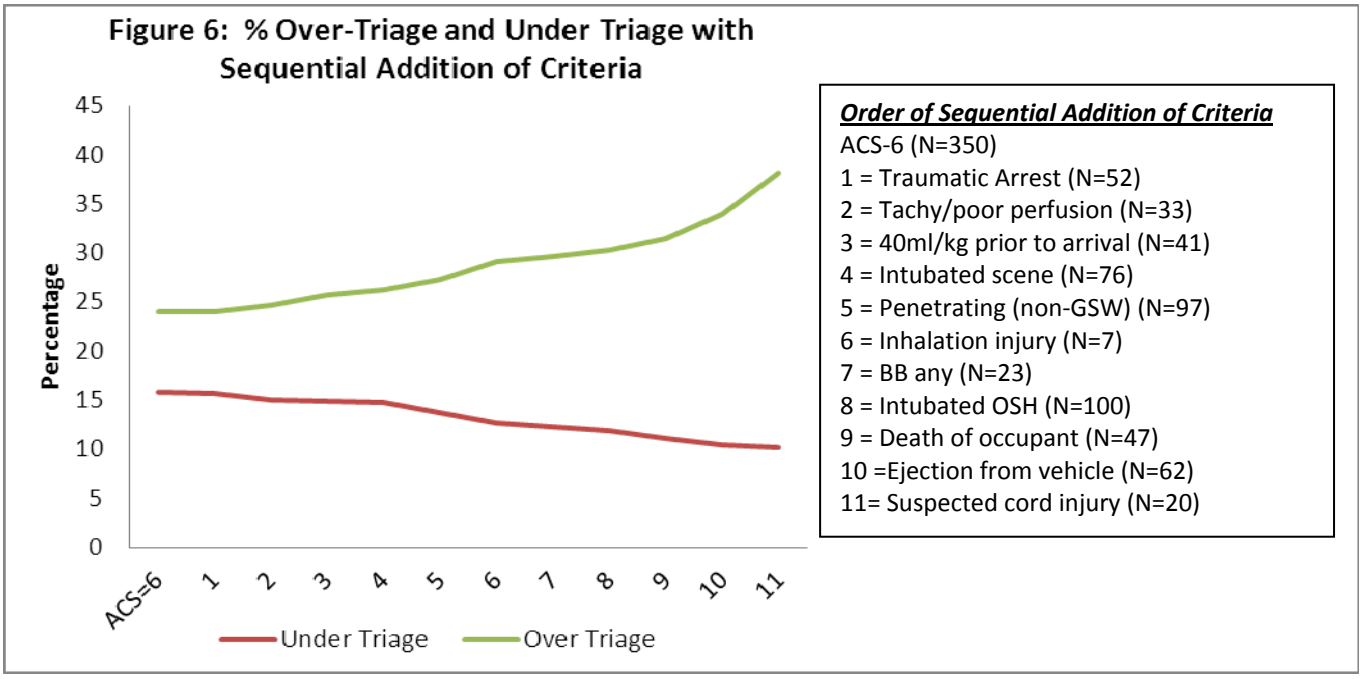
Predictive Value of Six ACS COT Mandated Criteria

The six mandated ACS COT criteria (ACS-6) for the initiation of adult / pediatric highest activation trauma resuscitations include the following: 1) age-specific hypotension; 2) respiratory compromise or obstruction; 3) transfer patients from another hospital who are receiving blood; 4) gun-shot wound to the abdomen, neck or chest; 5) Glasgow Coma Score (GCS) score of ≤ 8; and 6) deterioration of GCS score by 2. The category of ED discretion was not studied. All ACS-6 criteria were

included within the consensus list of criteria and specifically analyzed to compare how well they performed compared to the other consensus criteria.

Within the study population, 350 (53%) patients met at least one of the ACS-6 criteria. Utilizing only the ACS-6, 24% of patients would have been over-triaged and 16% would have been under-triaged. In order to evaluate the ACS-6 effectiveness, these six criteria were grouped together and utilized as baseline for over-triage and under-triage rate. Addition of criteria, based on the highest percent of time any resource is utilized, was then sequentially added to the ACS-6 group. With each addition of criteria, over-triage and under-triage were re-calculated and graphed. (Figure 6)

With the sequential addition of 11 criteria to the ACS-6, there is a steeper increase in over-triage with a more moderate and gradual decline in under-triage. With the addition of the first 4 criteria to the ACS-6 grouping, there is minimal change to either the over-triage or the under-triage status.



In specifically analyzing the predictive ability of each of the ACS-6 activation criteria, five of the six criteria exist within the top nine activation criteria. The ACS-6 specific requirement of "GCS deterioration by 2" generated less resource usage and was subsequently ranked lower (13 / 17) according to percentage of time a resource is utilized. (Table 6)

Table 6: Ranking of ACS-6 Criteria

Rank	Criteria
1	GSW any (N=34) *
2	Traumatic arrest (N=52)
3	Blood prior to arrival (N=18) *
4	Tachy/poor perfusion (N=33)
5	SBP <90 (N=44) *
6	40ml/kg prior to arrival (N=41)
7	Resp distress/failure (N=103)*
8	Intubated scene (N=76)
9	GCS<=8 (N=214)*
10	Penetrating (non-GSW) (N=97)
11	Inhalation injury (N=7)
12	BB any (N=23)
13	GCS deteriorating by 2 (N=94) *
14	Intubated OSH (N=100)
15	Death of occupant (N=47)
16	Ejection from vehicle (N=62)
17	Suspected cord injury (N=20)

***Criteria within ACS-6**

Various combinations of activation criteria can be utilized in the calculation of over-triage and under-triage rates. The table below outlines these various methodologies, listing their over-triage and under-triage rates for comparison. (Table 7)

Table 7: Comparison of Under-triage and Over-triage for specific criteria grouping

Ranking Options	Under-triage	Over-triage
All 23 criteria (ranked on % time used resources utilized)	9.5%	55.1%
Top 13 criteria (ranked on % time of resources utilized - to include all of the ACS-6)	10.5%	39.2%
Top 9 criteria (with GSW abdomen changed to GSW any); includes 5 of 6 ACS-6 criteria	16.9%	20.4%
ACS-6	15.9 %	24.1 %
ACS-6 + addition of 4 additional criteria based on % time of resources utilized (traumatic arrest, tachycardia/ poor perfusion, 40 ml / kg bolus prior to arrival, intubated at scene)	14.8 %	26.2 %

Under-triage

Under-triage can result in life-threatening injuries going undetected. In this study, 60 (9%) patients were in the under-triage category, met no activation criteria, but utilized an ED high level resource. Additional analysis was necessary for the under-triage population, in order to inspect for the potential of omitted triage criteria. The under-triage group and the remainder of the study population were compared and found to not be statistically different in the categories of median age, median ISS, % patients with ISS ≥ 15, median time to OR, and discharge to rehab. Statistically significant areas included the following: 1) time to ICU transfer, where the under-triage group took longer (76 minutes vs. 51.5 minutes), 2) mortality, where the under-triage group was much lower (1.7% vs. 14.3%) and disposition from the ED. A higher percentage of the under-triage patients were sent to the OR compared to the appropriately or over-triaged patients (52% vs. 19.5%), whereas a lower percentage of the patients who were under-triaged were sent to the floor compared to the appropriately or over-triaged patients (12% vs. 25%). (Table 8) One death occurred in the under-triage group, which consisted of an adolescent requiring intubation after a suicide attempt (ISS=43). In this circumstance, appropriate pre-hospital information was not relayed to the hospital.

Table 8: Demographic Comparisons of Under-triage and Non Under-triage Population

Variable	Under-triage (N=60)	Appropriate and Over-triage (N=596)	p-value*
Median Age (years)	7 (4,10)	8 (3,13)	0.17
Median ISS	10 (4,18)	10 (4,22)	0.97
Median Time to OR (minutes)	76 (47, 88)	51.5 (32, 88.5)	0.11
Median Time to ICU (minutes)	100 (85, 161)	68 (50, 101)	0.0002
Mortality	1 (1.7%)	71 (14.3%)	0.0091
ED Disposition			< 0.0001
ICU	21 (35%)	263 (44%)	
OR	31 (52%)	116 (20%)	
Morgue	0 (0%)	24 (4%)	
Floor	7 (12%)	147 (25%)	
Other	1 (2%)	46 (7%)	
Discharge to Rehab	4 (7%)	70 (13%)	0.21

*The Wilcoxon Rank Sum test was used for comparisons for the continuous variables. The Fisher Exact test was used for comparison for categorical variables. A p-value of <0.05 is considered significant.
**Median values reported using inter-quartile percentages (25%, 75%)

Of the 60 under-triage patients, 5(8.3%) required more than 1 resource during the ED resuscitation. Most common resources utilized were 11 patient intubations (18%), 7 patient fluid boluses of ≥ 40 ml / kg after arrival (12%), 7 patient transports to OR < 45 minutes after arrival (12%), 5 patients administered blood (8%), 5 patient transports to OR between 45 – 90 minutes after arrival (8%), and 1 patient required a central line insertion (2%). Twenty-two patients (37%) required either an intubation, emergent transfer to the OR within 45 minutes or blood administered during the resuscitation.

In analyzing this population, 31 patients (51.7%) had an ED disposition of OR; however, only 12 patients (20%) reached the OR within 90 minutes of arrival. Operative need for these 12 patients included the following: emergency craniotomy (N=4; ISS range 16-26); exploratory laparotomy (N=4; ISS range 10-20); repair of open fracture (N=2; ISS 10, 25); emergency airway (N=1; ISS 14); and an open skull fracture (N=1; ISS=10). Of note is at least 6 cases (10%; ISS range of 17-43) had inadequate pre-hospital information conveyed to the hospital staff. All 6 cases had physiological parameters which would have fit study criteria, and all eventually had the highest level trauma activation based on Emergency Department physician discretion. Of the total 60 under-triage patients, ED physician discretion for activation of highest level of resuscitation was only utilized for 16 patients (27%) while an additional 28 patients (47%) had a mid-level activation initiated. Sixteen patients within the under-triage group utilized a high level ED resource without any activation of the trauma team.

Discussion

Despite the presence of a tiered trauma system for the past decade, adult and pediatric trauma centers continue to struggle with a definitive list of highest level activation criteria. In mandating six criteria for highest level activation in 2002, the ACS COT attempted to match resources with the needs of the severely injured patient and the presence of an attending trauma surgeon at the resuscitation. However, trauma centers expanded this criteria leading to inconsistency, inefficacy of human resources and increased health care costs. This study of 656 traumatically injured children is our initial attempt to better understand and thus select pediatric triage criteria that will allow for the accurate prediction of resource needs for highest level trauma activations.

Basic to the foundation of this study, is our methodology of measuring over-triage, appropriate triage and under-triage for the most severely injured. The *Resources for Optimal Care of the Injured Patient: 2006* utilizes a general definition for under-triage – "triage decision that classified patients as not needing trauma center care when, in fact, they do". [1] By using this method, a target under-triage rate should be 1% or less. Conversely, over-triage is "over-utilization of finite resources" with an acceptable range of 25-50%.[1] For this study, the definitions for over-triage and under-triage are specific only to high level trauma activations; therefore, they have a much different connotation than the generally accepted definition than those recommended by the ACS COT.

In order to measure over-triage and under-triage, specific outcome measures needed to be identified. In the article by Steele et al. (2007), who previously investigated the ACS-6 criteria, the only ED resuscitative outcome measurement was "emergency transfer to the OR within an hour". Steele, et al. found that only 0.3% of the pediatric population required emergent transfer to the OR while over 23% of the pediatric population met at least one of the ACS-6 criteria. [42] They concluded that the ACS-6 were not good pediatric predictors for highest level activation. As many injured children are treated non-operatively and the benefits of the trauma team extend well beyond just operative management, we felt that this outcome measure was narrow in scope. In another study investigating pediatric activation criteria, Phillips et al (1996) utilized discharge data on level of injury as their outcome measurement. Phillips concluded that within their state pediatric trauma criteria, only GCS, ejection from vehicle, and penetrating injuries had a statistically significant impact on predicting major trauma in pediatric patients. In Phillip's study, over-triage was at an acceptable rate of 15%, with an unacceptable rate of 33% under-triage. [40] However, the intent from our study was not to validate whether the triage criteria predicted major trauma; but instead, to investigate what pediatric triage criteria utilized specific high level ED resources by the trauma team. Therefore, throughout this study, we believe that our operational definition of appropriate triage (i.e. criteria with ED resource use), over-triage (i.e. criteria without ED resource use) and under-triage (i.e. no criteria with ED resource use) is a strong methodology for comparison and development of conclusions.

The determination of which specific ED resources correlate with highest level trauma team activation was determined by consensus among a consortium of trauma experts. Within this determination, the following two issues generated additional discussion. An operational definition was established on a time cut-off between emergent and non-emergent chest tube insertion. For this study, only chest tubes placed within 30 minutes of arrival were included as a high level resource. However, it is recognized that emergent chest tubes may have been placed outside of that time frame. Secondly, it was recognized that an emergent disposition to the OR was a major resource need for the severely injured child. For statistical purposes, the categories were broken down to "less than 45 minutes" and "between 45 to 90 minutes". Concern was expressed that children would be included in the study who electively went to the OR quickly, possibly because of OR and / or surgeon availability. Specific analysis of the under-triage population did not validate that concern, as only 4 patients (7%) were questionable if the OR was emergent vs. non-emergent. These included: 1) 3 cases of exploratory laparotomy for possible bowel injury (ISS=10, 14, and 14); and 2) 1 case of OR for depressed skull fracture (ISS=10).

For this study, the categories of GSW, BB and penetrating injury (non-GSW) were specifically divided into body regions (i.e. head, neck, chest and abdomen) and analyzed individually. This made the analysis difficult, as in many of these categories the sample size was too small. In the category of GSW, there was much variation in the ranking of ED resource utilization. GSW to abdomen was consistently ranked high in ED resource utilization while GSW to chest and GSW to head had a more moderate ED resource utilization. GSW to neck, with only 2 patients in the study, was excluded but did use an average of 2 ED resources per case. With this larger than anticipated variation, the grouping of "GSW any" was included within the analysis.

Amputations were also included in this study with the decision to exclude any type of digit amputation within the overall criteria and only focus on amputations of above-wrists and above-ankle. We recognized that some emergent situations, specifically with immediate transfer to the OR, may include digit re-implantation. This specific scenario did occur with one of the under-triage population. In the final analysis, the category of amputations was eventually excluded due to small sample size;

however, consideration and additional research should continue regarding this criterion. In all three patient situations, a high number of ED resources were utilized. Consideration should be given to merging this specific mechanism of injury into the tachycardia / poor perfusion criteria.

In all multi-center studies, consideration needs to be given to practice-bias regarding ED treatment modalities during a trauma resuscitation. For example, a specific hospital may be more aggressive administering blood while another may be more aggressive toward early insertion of a central line. In order to assess for this potential bias, future detailed analyses will be required.

Multiple methods were examined to rank criteria: 1) average number of resources used per criteria; 2) percentage of time any resource utilized with a criteria; 3) percentage of time that two resources were utilized for a criteria; 4) mean ISS per criteria; and 5) ranked by under-triage. After a comparison analysis it became apparent that 9 criteria were consistently in the top of each ranking system. Given that our primary concern was the utilization of any resource requiring the trauma team we utilized the "percentage of time any resource utilized with a criteria" for the majority of our analyses.

One priority of this study was to evaluate the effectiveness of the mandated ACS COT criteria (ACS-6) for highest team activation. For this study, ED physician discretion was not prospectively evaluated. Within the study population, 350 (53%) patients met at least one of the ACS-6 criteria. Utilizing only the ACS-6 criteria, 24% of patients would have been over-triaged and 16% would have been under-triaged. It is significant that the under-triage is only 16% with the use of the 6 criteria and only decreases to 9% with the presence of all 23 criteria. Overall, the ACS-6 performed well in the context of over-triage and under-triage rates. The inclusion of additional criteria had little impact on under-triage but instead, continued to increase the over-triage rate.

Five of the 6 ACS-6 criteria were consistently listed within the top 10 criteria within the ranking system that was utilized for this study. Only "GCS deterioration by 2" was consistently ranked lower than the other 5. It was also noted that some of the non-ACS-6 criteria are actually included within the ACS-6 grouping. For example, a patient with a pre-hospital history of traumatic arrest should automatically be included in the ACS-6 grouping as they would fit the criteria of GCS< 8 or hypotension

in the field. A patient with an extremity amputation may or may not fit into a category of age-appropriate hypotension. With the deletion of the "GCS deterioration by 2" criterion, the addition of "tachycardia / poor perfusion" and "40 ml / kg bolus prior to arrival" (i.e. ACS-7), this change could potentially limit resource utilization for pediatric trauma resuscitations while continuing to maintain the acceptable over-triage and under-triage rates. (Table 10)

Table 10: Proposed Changes for Activation Criteria

Top 13 ranked triage criteria	**ACS – 6 (current)**	**ACS – 7 (proposed changes)**
GSW Any	GSW Any	GSW Any
Traumatic Arrest	Blood prior to arrival	Blood prior to arrival
Tachycardia / poor perfusion	SBP < 90 (age appropriate)	SBP < 90 (age appropriate) *To include traumatic arrest
Blood prior to arrival	Respiratory distress / failure	Respiratory distress / failure *To include intubation at scene
SBP < 90 (age appropriate)	GCS ≤ 8	GCS ≤ 8
40 ml / kg bolus prior to arrival	GCS deterioration by 2	Tachycardia / poor perfusion
Respiratory distress / failure		40 ml / kg bolus prior to arrival
Intubated at scene		
GCS ≤ 8		
Penetrating (non GSW) chest		
Inhalation injury		
BB any		
GCS deterioration by 2		

The under-triage population (N=60) was specifically analyzed to assess if any criteria was potentially missing from the consensus list of activation criteria. The ISS was comparable to the rest of the patient population, leading one to believe that the under-triage category was just as severely injured. On careful analysis of this group, no obvious missed criterion was apparent. In assessing the ED

resources utilized by this group, three important resources utilized were intubation, patients requiring transport to the OR in 45 minutes and patients requiring blood. These accounted for 22 patients (37%) of the under-triage group. One repeated validation that was obtained from analysis of the under-triage group was the importance of reliable pre-hospital information on clinical parameters. At least 6 patients (10%) would have been met criteria if there had been improved communications from our pre-hospital colleagues. Examples of this which would have decreased the under-triage group include: 1) pre-hospital information conveyed as "intermittently arousable" with patient requiring emergent craniotomy within 45 minutes of arrival (ISS=25); 2) pre-hospital information only as "less responsive" with patient requiring intubation (ISS=17); 3) pre-hospital information conveyed as "sometimes unconscious" with patient requiring intubation (ISS=17). Of these 6 under-triage patients, the inaccurate information provided to the hospital were all regarding assessment of GCS in children. Further attention should be concentrated on providing additional training on assessment of pediatric GCS to the pre-hospital personnel and to the hospital personnel taking the calls on how to appropriately interpret these findings.

Information on the sensitivity of specific activation criteria is vital for trauma centers as they attempt to establish an acceptable over-triage and under-triage rate. For many institutions, the aspect of under-triage is probably the most important to assess. However, assuming that the decrease of under-triage is the main ingredient of the equation can be a perilous decision. As a result, over-triage can precipitously increase the cost, both in finances and in the human resource aspect of personnel. Some argue that cost should not be a factor when there is consideration of a child's life. However, in this era of cost containment in health care, balancing these two measures should continue to be priority. The goal of this study was to take an important first step toward improving the quality and timeliness of care for the severely injured child in a fiscally responsible manner. Trauma resuscitations, especially at the highest level are expensive endeavors as evidenced by resource and personnel utilization. For the participating hospitals in this study, the average charge for highest activations was $7,843. If only the ACS-6 criteria were utilized, 55 highest activation resuscitations would have been eliminated or reduced to a mid-level activation; thus with a potential savings between $230,000- $431,000. This variation in

cost savings is dependent on whether the activation charge is eliminated or reduced to a mid-level activation. This does not take into account the financial impact of mandating personnel for the highest activation, specifically the attending / fellow pediatric surgeon and frequently utilizing anesthesia and operating room personnel.

Challenges / Limitations

A major challenge for appropriate trauma activation, whether at a mid-level or the highest level, is the timeliness and quality of the verbal report from referring hospitals, inter-facility transport service or EMS squad. This is especially true for pediatrics, as many individuals are not as comfortable assessing the younger injured child. In this study, some criteria were easily identified and reported while other criteria, such as tachycardia with poor perfusion, and respiratory distress / failure are more subjective. If this information was not adequately reported by the pre-hospital or referring institutions, then patients were included within the under-triage category. The criteria GCS ≤ 8 appears easily quantifiable; however, obtaining this information on a pediatric child, along with a constantly changing neurologic status, makes this criterion sometimes difficult to verbally and accurately convey. Consistency and increased specific definitions from pre-hospital personnel on these parameters would assist trauma center personnel and decrease the need for interpretation.

A limitation for this study was the infrequency of specific injuries, leading to small sample size within the category; thereby, removing these from the study analysis. Interestingly, amputations (above wrist and above ankle) and gun-shot to neck utilized a high level of resources although they infrequently occurred. Additional research into these areas with a larger sample size would be of benefit.

Attempts were made to standardize each definition for the 9 pediatric trauma centers that participated, yet compliance of this was dependent on each participating hospital. A data dictionary of each criterion was developed by the 9 Trauma Program Managers. Discussion on various scenarios and clinical indicators occurred via phone conferences before the start of the research project. Three additional points of demographic information, such as insurance coverage and whether the activation was

upgraded / downgraded during the ED stay would have been helpful to the study analysis. A break-down of ED Disposition of "Other: another institution" or "Discharge home" would have benefited analysis.

Conclusion

Highly sensitive pediatric triage criteria are needed in order to appropriately initiate the highest level of trauma team activation. The ACS-6 mandated criteria performed well when evaluating this by over-triage and under-triage rates of the highest injured pediatric patients. It is generally accepted that some amount of over-triage is necessary to minimize the risk of under-triage. The inclusion of additional criteria beyond the ACS-6 had a small impact on under-triage yet continued to increase the over-triage rate significantly. Small revisions in the ACS-6 criteria for the pediatric population may potentially have some benefits. Additional education on assessment of GCS in the pediatric population and / or interpretation of pre-hospital information may assist with appropriate highest level trauma team activation.

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Appendix 1: Activation Criteria with Data Collection Definitions

Activation Criteria	Data Definitions
Traumatic Arrest	Cessation of cardiac activity
Respiratory distress / failure from scene	Outwardly evident, physically labored respiratory effort; dyspnea to include SOB; retractions; stridor; not included - patient with ongoing CPR
Intubated patient from referring facility	LMA included. Include when aeromedical personnel intubates before leaving referring hospital.
Intubated patient from scene	LMA included
Tachycardia with poor perfusion	Age appropriate HR to be utilized
≥ 40 ml / kg fluid bolus before patient arrival	Regardless of type of fluid
Blood received any time before patient arrival	Any amount
GCS < 8	Glasgow Coma Score, utilizing all 3 components of eye, verbal and motor noted in the field. Check this if patient was intubated due to a reported GCS < 8.
GCS deteriorating by 2 (any time prior to patient arrival)	
Suspected spinal cord injury with motor deficit	Include any observed/reported motor deficit
Burns > 30% body surface area (BSA)	As estimated at scene
Suspicion of inhalation injury (chemical / thermal)	
Systolic blood pressure (SBP) < 90 (with age appropriate definitions) < 1 = 60; ages1-2 = 70; ages 3-5 = 75; ages 6-12 = 80	At least one episode in the prehospital setting, referring hospital or during transport.
Extremity amputation (above ankle)	To include partial or complete amputation
Extremity amputation (above wrist)	To include partial or complete amputation
Penetrating wound (non GSW) to head	A wound made by a sharp object that breaks the skin and enters into a cavity, organ or body area. Must be more than a superficial laceration.
Penetrating wound (non GSW) to neck	See above
Penetrating wound (non GSW) to chest	See above
Penetrating wound (non GSW) to abdomen	Penetrating to at least the level of the fascia
GSW to head	
GSW to neck	
GSW to chest	
GSW to abdomen	
BB to head	
BB to neck	
BB to chest	
BB to abdomen	
Ejection (car / pick-up truck / motorcycle)	Not include: car surfing, ATV, motorized scooter, Amish buggy
Death of occupant within same vehicle	Not to include death in other vehicle

Appendix 2: Emergency Department Resources

- Intubation / Re-intubation
- Administration of blood
- Fluid Bolus (≥ 40 ml / kg since time of arrival)
- Arrival time to Operating Room transfer < 45 minutes after patient arrival
- Arrival time to Operating Room transfer 45 – 90 minutes after patient arrival
- IO insertion
- Pericardiocentesis
- CPR / traumatic arrest
- Needle decompression
- Central line insertion (femoral, subclavian, etc.,)
- Chest tube insertion within 30 minutes after patient arrival
- Open thoracotomy