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Using trauma video review to search for the Goldilocks pre-activation time

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ABSTRACT

Objectives We sought to determine the optimal time to pre-activation for trauma team activation that resulted in maximum team efficiency, measured by the time to complete critical actions (TCCAs) during resuscitation. We hypothesized that there exists a time window for trauma team pre-activation that minimizes TCCA.

Methods This is an exploratory retrospective analysis of video-reviewed traumas at a level 1 trauma center from January 1, 2018 to 28 February, 2022 that received the highest trauma team activation and had a pre-arrival notification. A total of 11 TCCA categories were calculated using video timestamps. To compare TCCAs from different categories, normalized TCCAs (nTCCAs) were calculated by dividing each TCCA by the median time of its category. Pre-activation times were categorized into three groups: long pre-activation (≥8 min), mid pre-activation (≥4 and ≤7 min), and short pre-activation (≥0 and ≤4).

Results There were 466 video-recorded level 1 trauma activations, which resulted in 2334 TCCAs. Of the 466 activations, 152 occured on the patient's arrival (0 min pre-activation). The majority (425) of patients had a pre-activation time of <7 min. Pre-activation of 4–6 min resulted in all but blood transfusion TCCAs being <15 min. Furthermore, mid pre-activation category corresponded to the most efficient trauma teams, with nTCCAs significantly shorter (median=0.75 (IQR 0.3–1.3)) than long (median=1 (IQR 0.6–2)) or short activation groups (median=1 (IQR 0.6–1.6)). A greater proportion of nTCCAs were shorter than their category median in the mid pre-activation category compared with long and short categories (59.1% vs 48.3% and 40%, respectively; p<0.01).

Conclusions In this exploratory study, a pre-activation time of 4–7 min is associated with the best team efficiency as measured by TCCAs during trauma team activations. This timeframe may be an optimal window for trauma team activations but needs prospective and external validation.

Level of evidence Level 4 retrospective exploratory study

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ A designated trauma team activation prior to patient arrival improves clinical outcomes, but the optimal timing of trauma team activation remains unclear.
⇒ Activating the trauma team too early may result in resource misallocation, while activating them too late may delay critical interventions.
⇒ We hypothesize that there is an optimal time window for trauma team pre-activations that leads to improved task completion, which ultimately may improve patient outcomes.

WHAT THIS STUDY ADDS

⇒ There is an optimal pre-activation time to minimize the time to complete critical actions.
⇒ This Goldilocks timeframe was between 4 and 7 min before patient arrival at our center.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Future studies will attempt to elucidate if this same Goldilocks timeframe shows highest efficiency in other trauma centers and to identify which specific events are being affected by pre-arrival preparation.
⇒ Improving time to completion of critical actions may improve trauma patient outcomes by giving them the timely critical care they need.

BACKGROUND

Traumatic injuries are a major cause of morbidity and mortality worldwide, and rapid management of these injuries is critical for optimizing patient outcomes. Trauma teams, consisting of a multidisciplinary group of healthcare professionals, are responsible for coordinating and implementing the management of trauma patients. One way to improve the timeliness and effectiveness of trauma care is to activate the trauma team prior to the patient's arrival, a process known as pre-activation.[1] Pre-activation allows for preparation and anticipation of patient's needs and coordination of resources to expedite care.

It has been well documented that a designated trauma team activation prior to patient arrival improves clinical outcomes.[2] However, not many studies have investigated the optimal timing of trauma team activation. A study from a Norwegian tertiary trauma center evaluated trauma team activation timing and subsequent time to chest X-ray in the trauma bay as well as emergency department (ED) length of stay and found that proactive team activation of at least 10 min led to reduction in time to chest X-ray. They found that proactive allocation of tasks and organization prior to trauma patient arrival led to improved performance and patient care.[1]

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While prenotification (the process of notifying the receiving hospital of the trauma patient prior to arrival) can improve patient outcomes, the optimal timeframe for pre-activation of the trauma team is unclear.[3] Not all prenotifications lead to pre-activation—in many hospitals, the trauma team is not automatically activated for every trauma prenotification but rather on a case-by-case basis to ensure efficient use of resources. Activating the trauma team too early may result in the team becoming distracted and resource misallocation, while activating them too late may delay critical interventions and compromise patient outcomes. Therefore, it is important to find a timeframe of when to pre-activate the trauma team, as the optimal time may not be in concurrence with the prenotification. In our exploratory work, we hypothesize that there is an optimal time window for trauma team pre-activations that leads to improved task completion and higher efficiency by the trauma team.

METHODS

Study setting

This retrospective explorative study was conducted at an American College of Surgeons verified level 1 trauma center from January 1, 2018 to 28 February 2022. The hospital is a 756-bed quaternary care facility in the suburban metropolitan area. It operates on a three-tier trauma activation protocol, with level 1 being the most severe and calling for full trauma activation. All trauma activations of the highest severity are audio and visual recorded as a part of ongoing quality improvement. While all recordings are reviewed, only about half are identified for closer review and data collection for quality improvement and research by an experienced investigator.

Study design

As per regional protocol, Emergency Medical Service providers are required to provide a prenotification report for every patient transported. These reports are placed through Medical Control, which is a third-party government-run intermediary. This prenotification report is then relayed to the hospital, where the charge nurse or emergency physician determines whether the patient meets the activation criteria (systolic blood pressure <90 mm Hg, penetrating injury to head, neck, or torso or above knee and elbow, Glascow Coma Score <10, interfacility transferred patients receiving blood transfusion or intubated, unprotected airway, tourniquet applied to extremities, paralysis, pulseless extremity, amputation above ankle or wrist, a known intracranial bleed with associated midline shift of over 10 mm, or emergency medicine (EM) attending physician discretion).

When a level 1 activation occurs, a hospital-wide notification is given through the overhead system and an alphanumeric one-way page is sent to the trauma team. The time between when this occurs and the patient's arrival is defined as the pre-activation time measured in minutes (figure 1). In cases where trauma activation occurs on the patient's arrival to the ED, these pre-activation times were classified as zero. For this reason, for this study the term pre-activation time was used rather than pre-arrival time as pre-arrival time assumes the call occurred before arrival of the patient. Patients for whom trauma activation occurs after their arrival (>1 min difference between their ED arrival time and activation time) were excluded from this analysis. For this study, we focused exclusively on the highest severity (level 1) activations, which require a full trauma team response and are video reviewed for quality improvement. Exclusion criteria was limited to unavailability of video review data. Additionally, simultaneous or dual trauma activations occur infrequently (<1%) at this site, and therefore these cases were not differentiated from normal trauma activations in data analysis.

At all times during the day and night, the trauma team consists of the emergency attending and resident physicians, emergency nursing staff and technicians, radiology technician and the trauma attending and resident physicians, with additional support from neurosurgery residents and respiratory therapists not required per protocol but often responding to trauma pre-activations. The blood bank also receives a notification in anticipation of immediate release of blood products. The Trauma Program Manager or Clinical Quality Improvement Specialist selects videos with potential for quality improvement for closer review and abstracts Video Assessed Micro-Data (VAMD), which are specific data points related to trauma care. These VAMDs include timestamps such as time of patient arrival and disposition from the trauma bay, as well as various time of actions critical to the care of the traumatically injured. These are then used to calculate the time to complete critical actions (TCCAs). These critical actions were chosen by expert consensus. Each TCCA was defined as the difference between arrival and completion of each critical action in minutes (figure 1). TCCAs were deemed 'assessed' or completed when the evaluation in accordance with Advanced Trauma Life Support (ATLS) algorithms were performed and necessary interventions were completed. TCCAs, demographic, and relevant clinical data are subsequently stored in the trauma patient registry. All reviewers regularly met and followed clear definitions of each task to identify the corresponding VAMD timestamp (ie, the time of tracheal tube placement was defined as the time of confirmation of successful tracheal intubation using two methods such as auscultation and end-tidal CO_2). The trauma video review process has been established at our institution since 2015 and has been led by one of the investigators (CM), who is the Trauma Program Manager, in collaboration with Clinical Quality Improvement Specialist (CQIS). They met regularly each week to clarify discrepancies in data collection. They have both been trained by another investigator (MB).

Based on expert consensus, the ATLS guidelines and video reviews of prior trauma activations showing that the tracheal intubation process took the longest time among critical tasks and had the most delays, as well as considering the importance of blood product transfusions, we focused on 11 key time points extracted from this dataset. These time points correspond to the airway, breathing, circulation, disability (ABCD) of ATLS care,

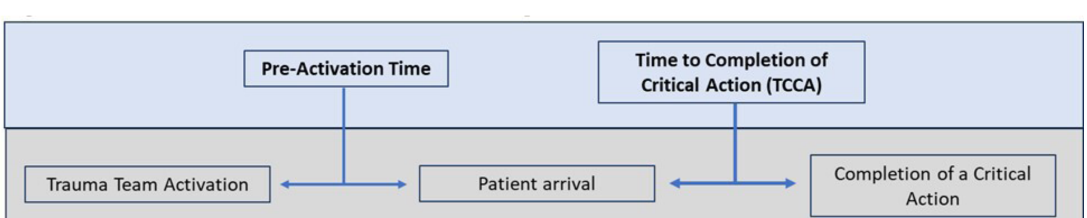

Figure 1 Definitions for pre-activation time and time to completion of critical action.

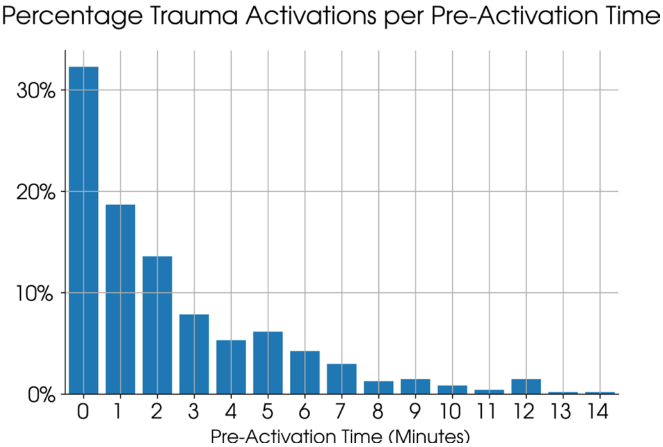

Figure 2 Distribution of pre-activation times.

Table 1 Time to completion of critical actions frequency by category

Category	Number of patients	Missing data
Airway assessed	440	26
Breathing assessed	445	21
Circulation assessed	416	50
Disability assessed	387	79
Decision to intubate	125	N/A
RSI ordered	115	N/A
RSI available	107	N/A
RSI administered	100	N/A
ETT placement	113	N/A
eFAST	26	N/A
Blood transfusion	60	N/A

eFAST, extended focused assessment with sonography in trauma; ETT, endotracheal tube; N/A, not applicable; RSI, rapid sequence induction.

the receipt of emergent blood product transfusions, extended focused assessment with sonography in trauma (eFAST), and key steps of tracheal intubation (decision to intubate, medications for rapid sequence intubationordered, ready, and administered, and tracheal tube placement). Intubation was always performed by an EM physician. If the trauma physicians were not present, EM physicians would regardless start evaluation and care for the patient, including critical actions, as soon as the patient arrived. The 11 TCCAs comprised our primary outcome. The independent variable or 'exposure' was the pre-activation time. This study was conducted in accordance with Strengthening the Reporting of Observational Studies in Epidemiology guidelines.[4]

Statistical analysis

Demographic data were extracted from the trauma registry, and a descriptive analysis was conducted.

Statistical significance was defined as $p<0.01$ throughout, except where noted. A more robust p value was chosen due to the multiple elements of analysis. To compare TCCAs across different action categories, normalized TCCAs (nTCCAs) were calculated by dividing each TCCA by the median time of the corresponding category. Each category of critical action has its own mean, and without normalization, we would not be able to compare the categories with each other. Comparison of the categories was critical to assess for a difference in overall task completion.

Pre-activation times were defined as starting at the time of trauma activation (figure 1), with their distribution presented in figure 2. After a minute-by-minute analysis of nTCCA medians by pre-activation time, we categorized pre-activation times into three groups: long pre-activation (≥8 min), mid pre-activation (≥4 and ≤7 min), and short pre-activation (≥0 and ≤3 min). All times in the dataset were recorded in minutes, meaning that both 3:01 and 3:59 were counted as within 3 min. Differences in the medians of nTCCAs among the three pre-activation groups were tested using the Kruskal-Wallis test. The proportions of nTCCAs ≥1 in each group were compared using Fisher's exact test. All calculations, database analysis, tables, and figures were performed using Python V.3.1 software in conjunction with SciPy[5] and PANDAS.[6]

RESULTS

During the study period, there were 466 level 1 trauma activations, which resulted in 2334 TCCAs. The discrepancy between the number of activations and TCCAs available for analysis is due to the fact that not all patients required tracheal intubation, which resulted in the removal of five TCCAs from those activations. Table 1 shows the number of instances for each TCCA category reported, along with the number of missing for each. The missing data were often the result of data entry errors, and in rare instances, the inability to collect these data from the video review. The median age of patients was 53 (IQR 34, 71), with the majority being male (71%). There was a higher proportion of penetrating injuries in mid pre-activation time group (25.2%) compared with the long (16.9%) and short (16.9%) pre-activation time groups ($p=0.04$). Further cohort demographics, including race, Glasgow Coma Scale, injury type, and mechanism of injury, can be seen in table 2. Of the 466 activations included in the study, 152 (32.6%) occurred within a minute of the patient's arrival. The percentage of patients admitted during peak time (07:00 to 19:00 hours) also varied between the groups, with the short pre-activation group having the fewest (52%) arriving during peak times compared with the long pre-activation group, which had the highest (71%) ($p=0.04$). Of the TCCAs, the decision to intubate had the shortest median time (2 min), and endotracheal tube placement had the longest (8 min). Airway, breathing, and circulation clearance occurred within a median of 4 min (figure 3). Blood transfusions in the ED were administered to 60 patients (13%), with a median time of 10 min. There was no statistically significant difference between the pre-activation groups with respect to proportion receiving blood transfusions or their median time to transfusions (table 2). The majority (425, 91.2%) of patients had a pre-activation time of <7 min. Pre-activation times of 4–6 min before arrival resulted in all TCCAs being shorter than 15 min, except for blood transfusions, where three patients had blood transfusion TCCAs of 19, 26, and 28 min (figure 4). Mid pre-activation times resulted in the most consistently efficient trauma teams, with nTCCAs significantly shorter than those in the long or short activation groups (median of 0.75 (Q1–Q3: 0.3–1.3) vs 1 (Q1–Q3: 0.6–1.6); and 1 (Q1–Q3: 0.6–2.01.6), respectively, $p<0.01$ for both) (figure 5).

The proportion of nTCCAs strictly below 1 was significantly higher in the mid group compared with the long and short pre-activation groups (59.1% vs 48.3% and 40%, respectively, $p<0.01$ for both). This pattern held true and was statistically significant after controlling for intubation, peak-time admission (07:00 to 19:00 hours), transfer-in rates, and attending response time.

Table 2 Patient cohort demographics, including age, race, ISS, and MOI

Variable	Overall, n=466*	Short pre-activation, n=338*	Mid pre-activation, n=87*	Long pre-activation, n=41*	P value†
Age					0.165
Median (IQR)	53.0 (34.0, 71.0)	54.5 (33.0, 71.8)	47.0 (33.5, 63.0)	60.0 (38.0, 76.0)	
Female	136/466 (29%)	103/338 (30%)	21/87 (24%)	12/41 (29%)	0.511
BMI (kg/m²)					0.012
Median (IQR)	25.4 (22.3, 29.4)	25.7 (22.7, 29.7)	26.0 (21.4, 29.7)	22.2 (21.2, 25.8)	
Race					0.677
White	166/423 (39%)	119/307 (39%)	30/78 (38%)	17/38 (45%)	
Black	101/423 (24%)	77/307 (25%)	15/78 (19%)	9/38 (24%)	
Asian	45/423 (11%)	31/307 (10%)	12/78 (15%)	2/38 (5.3%)	
Other	111/423 (26%)	80/307 (26%)	21/78 (27%)	10/38 (26%)	
ISS					0.110
ISS≤8	161/431 (37%)	112/310 (36%)	35/83 (42%)	14/38 (37%)	
9≤ISS≤15	94/431 (22%)	68/310 (22%)	21/83 (25%)	5/38 (13%)	
16≤ISS≤24	71/431 (16%)	52/310 (17%)	15/83 (18%)	4/38 (11%)	
25≤ISS	105/431 (24%)	78/310 (25%)	12/83 (14%)	15/38 (39%)	
GCS					0.311
≥13	258/466 (55%)	182/338 (54%)	54/87 (62%)	22/41 (54%)	
9–12	38/466 (8.2%)	29/338 (8.6%)	8/87 (9.2%)	1/41 (2.4%)	
≤8	170/466 (36%)	127/338 (38%)	25/87 (29%)	18/41 (44%)	
ED LOS (m)					0.396
Median (IQR)	64.0 (44.0, 199.0)	64.0 (43.8, 182.5)	68.0 (48.0, 293.0)	55.0 (35.8, 249.0)	
ICU LOS (days)					0.751
Median (IQR)	4.0 (2.0, 7.0)	4.0 (2.0, 7.0)	4.0 (2.0, 8.0)	3.5 (2.0, 7.5)	
Total LOS (days)					0.701
Median (IQR)	8.0 (4.0, 15.0)	8.0 (4.0, 15.0)	7.0 (3.0, 18.0)	7.0 (3.0, 13.5)	
Days on ventilator					0.554
Median (IQR)	2.0 (2.0, 6.5)	2.0 (2.0, 7.0)	2.5 (2.0, 6.0)	2.0 (1.0, 5.3)	
Intubation	128/466 (27%)	89/338 (26%)	27/87 (31%)	12/41 (29%)	0.657
Transfusions in ED	60/466 (13%)	44/338 (13%)	10/87 (11%)	6/41 (15%)	0.875
Time to ED transfusion (min)					0.202
Median (IQR)	13.0 (10.0, 21.5)	16.0 (11.0, 23.0)	10.0 (8.5, 17.5)	10.0 (8.3, 17.0)	
Attending response time (min)					<0.001
Median (IQR)	2.0 (0.0, 4.0)	3.0 (1.0, 4.0)	0.0 (0.0, 1.0)	0.0 (0.0, 0.0)	
Injury type					0.042
Blunt	376/461 (82%)	280/334 (84%)	62/86 (72%)	34/41 (83%)	
Penetrating	85/461 (18%)	54/334 (16%)	24/86 (28%)	7/41 (17%)	
MOI					0.178
Fall	180/466 (39%)	143/338 (42%)	22/87 (25%)	15/41 (37%)	
Motor Vehicle (MV) occupant	63/466 (14%)	41/338 (12%)	17/87 (20%)	5/41 (12%)	
MV pedestrian	49/466 (11%)	34/338 (10%)	10/87 (11%)	5/41 (12%)	
Cut/Pierce	48/466 (10%)	32/338 (9.5%)	14/87 (16%)	2/41 (4.9%)	
Firearm	38/466 (8.2%)	25/338 (7.4%)	8/87 (9.2%)	5/41 (12%)	
MV motorcycle	21/466 (4.5%)	16/338 (4.7%)	2/87 (2.3%)	3/41 (7.3%)	
Struck by or against	11/466 (2.4%)	7/338 (2.1%)	4/87 (4.6%)	0/41 (0%)	
Other	56/466 (12%)	40/338 (12%)	10/87 (11%)	6/41 (15%)	
Transfer in	142/466 (30%)	124/338 (37%)	12/87 (14%)	6/41 (15%)	<0.001
Peak time adm. (07:00 to 19:00 hours)	257/466 (55%)	176/338 (52%)	52/87 (60%)	29/41 (71%)	0.048

*n/N (%).
†Kruskal-Wallis rank sum test; Pearson's χ^2 test; Fisher's exact test.
Adm., admission; BMI, body mass index; ED LOS, emergency department length of stay; GCS, Glasgow Coma Scale; ICU LOS, intensive care unit length of stay; ISS, injury severity score; MOI, mechanism of injury.

DISCUSSION

In this exploratory study, we have shown an optimal pre-activation window of 4–7 min before trauma patient arrival. We have used VAMDs to derive TCCAs as a marker of team efficiency in the early phase of trauma care. It is important to note that these optimal timeframes for pre-activation are only applicable to TCCAs directly measured in this study and their effects on unmeasured outcomes and factors not discussed here remains unknown and must be subject to further studies. With this in mind, the efficiency 'window' of 4–7 min for pre-activation still has several important implications.

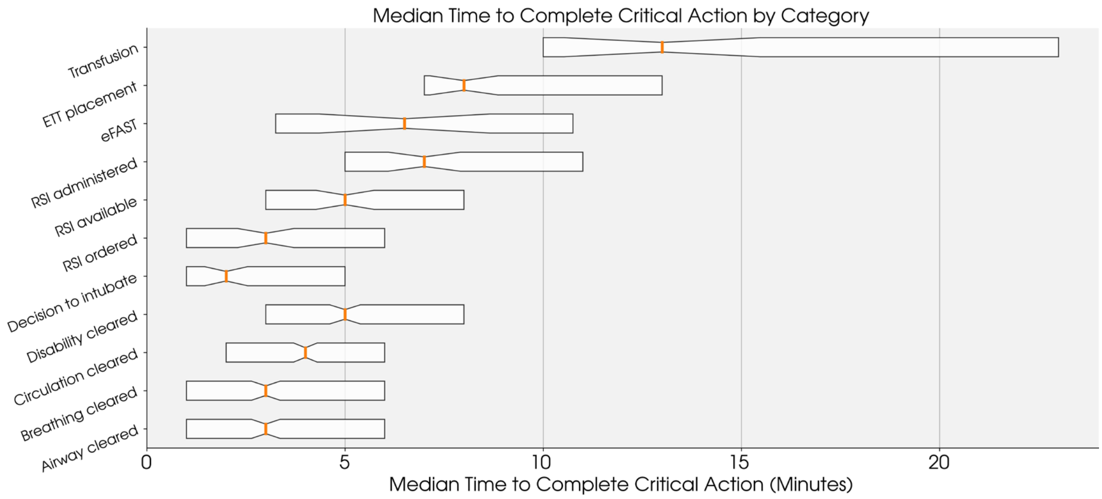

Figure 3 Median and IQRs of time to complete critical action (TCCA) by category. TCCAs were deemed 'assessed' or completed when the evaluation in accordance with ATLS algorithms were performed, and necessary interventions were completed. eFAST, extended focused assessment with sonography in trauma; ETT, endotracheal tube; RSI, rapid sequence intubation.

First, we found that having several minutes to prepare for an incoming patient leads to better team efficiency, and our data show that an overabundance of time can be detrimental to optimal trauma patient resuscitation. A prolonged period (in this case, ≥8 min) between trauma team activation and patient arrival led to an increased time to completion of critical actions. This could be due to the trauma team having excess downtime and thus risking distraction before patient arrival. As noticed by our video review, team members may frequently need to step away to address other patients' needs or respond to queries from other team members. Trauma activations necessitate a large amount of hospital resources, and these additional distractions can put unnecessary strains on the hospital system. Indeed, a study of pre-activation showed that only 4% of staff deemed not necessary for the care of the patient left before the conclusion of initial treatment.[7]

While the goal of trauma care is improved survival and diminished morbidity, demonstrating meaningful improvement in these outcomes is increasingly difficult, owing to improvements in care.[8 9] Therefore, proximate outcomes such as shorter TCCA is a reasonable surrogate. This relies on the assumption that faster care leads to less morbidity and mortality by shortening time to life-saving interventions, such as re-establishing airway and respiratory support, blood transfusions, and hemorrhage control.[10–12] Studies of the use of checklists in trauma focused on time to task completion.[13 14] Many prehospital studies similarly show shorter transport times lead to improved outcomes.[15 16]

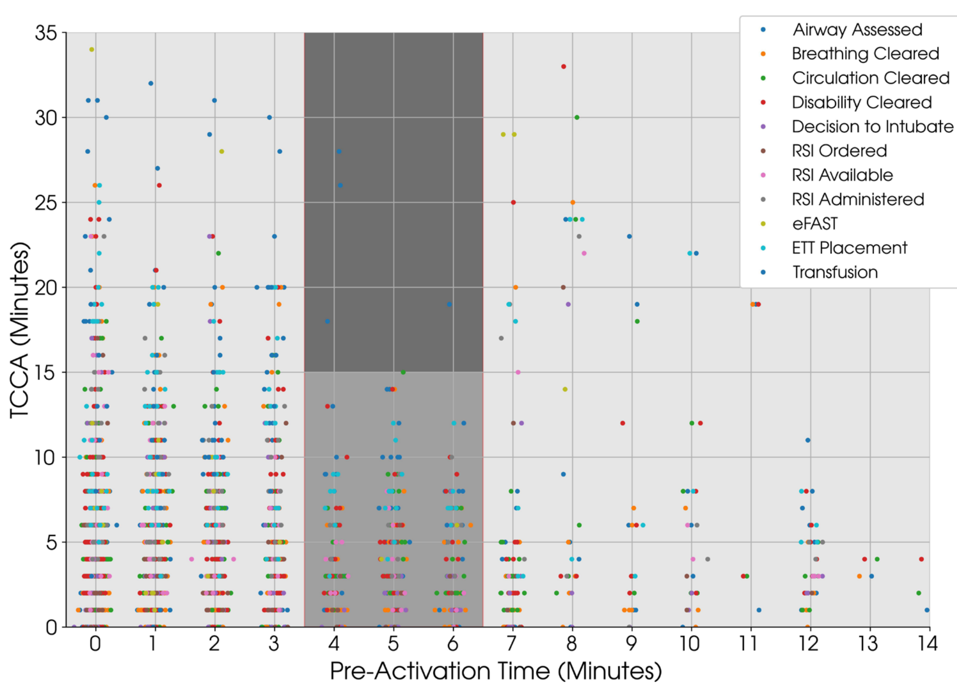

Figure 4 Time to complete critical events versus pre-activation times. Different types of events are shown in different colors. A slight jitter has been applied to show density. Shaded region indicates apparent concentration of shorter time to complete critical events. eFAST, extended focused assessment with sonography in trauma; ETT, endotracheal tube; RSI, rapid sequence intubation; TCCA, time to complete critical action.

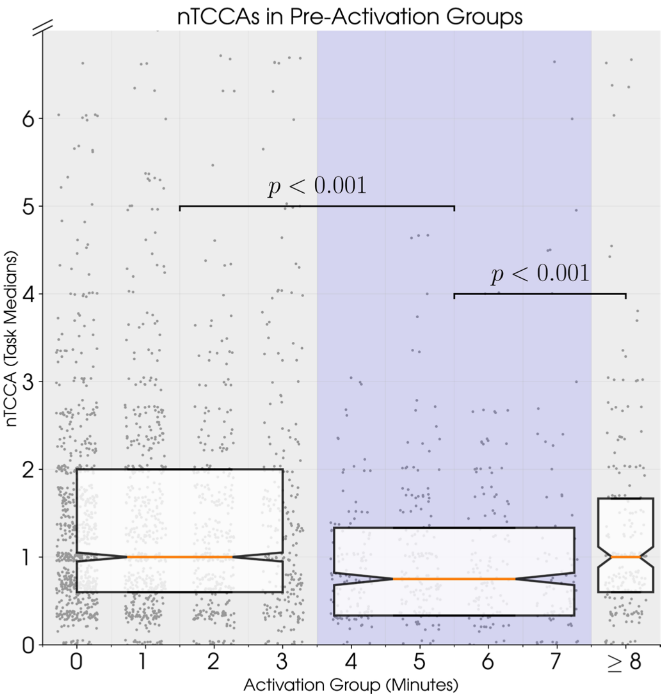

Figure 5 Average normalized time to complete critical actions (nTCCAs) versus pre-activation time. Values under 1 indicate above-average performance. Black vertical lines are SEM. P value brackets indicate individual comparisons between elements in either group.

Arguably, the most time-sensitive tasks in the care of trauma patients are ensuring a patent airway, effective breathing, and perfusing circulation, along with a rapid assessment of neurological function and the extent of injuries. These are highlighted in the Airway, Breathing, Circulation, Disability, and Exposure (ABCDE) of the ATLS algorithm. Thus, it is reasonable to assume faster performance of the above tasks could decrease morbidity and mortality. We believe TCCAs, derived from meticulous collection of VAMDs, are a novel and objective way of measuring trauma team performance.

Ahmed *et al* also identified a correlation between notification time and the percentage of required team members who were present at the time of patient arrival.[17] On video review, we similarly noticed that increased pre-activation time can lead to an excess of team members inside the trauma bay, thus leaving room for miscommunication, a louder atmosphere, and role confusion. However, we did not examine how much of the pre-activation time was spent enroute to the trauma bay and preparing versus waiting idly in the trauma bay. Our institution's policy is to be prepared within 5 min, and on average, our trauma service meets this requirement.

While previous studies focused on giving ample preparation time, there are no studies investigating the potential 'opportunity costs' of a prolonged pre-activation time. Intuitively, given the vast array of resources that is called on for trauma pre-activation, it makes sense that requiring these clinicians to abstain from caring for other patients may have negative consequences. In many instances where a pre-activation is called a long time before patient arrival to the trauma bay, both the EM and trauma surgery clinicians will attempt to attend to other patients' care, which could lead to the loss of focus and distractions. While more pre-activation time can give the team more time to prepare and therefore appropriately intervene, there seems to be a limit to this advantage. For example, timely blood transfusions can be life-saving in trauma patients with hemorrhagic shock. In our cohort, the median time to blood transfusion was 16 min for the short pre-activation group, whereas the mid and long groups both had a median time of 10 min.

The transfer-in group of patients in this study represented a unique challenge. Since the transfer-in group had about twice as many patients in the short pre-activation group, and since we have found that shorter pre-activation leads to worse team performance in terms of TCCAs, we feel that the ideal pre-activation time should become part of our transfer protocol, with automated trauma activation page being sent out within 6–7 min of patient's arrival. It is unclear why the transfer-in group had a higher percentage of short pre-activation times, given that their transport is coordinated through the transfer center.

Due to the low volume of level 1 trauma activations at our hospital, this study spanned 4 years and has several limitations. First, it did not directly investigate patient-oriented outcomes, such as mortality and length of hospital stay. This was partly due to the low mortality rate among our population and the complex contribution of other explanatory variables to these patient outcomes. Another limitation is the potential for selection bias for less-than-optimal trauma team performance—while there was a total of 988 level 1 activations during this study period, only 466 were chosen for quality improvement review based on perceived potential issues during resuscitation. Additionally, because simultaneous trauma activations rarely occur at our institution, we did not account for its potential effects. On closer review, there were only six cases of simultaneous activations within 5 min of each other in our cohort, which is <1% of the cases, so the effect of these cases is likely minimal. Pre-arrival time-outs with a checklist are part of the formal trauma team response; however, these time-outs were not consistently video recorded so we are unable to assess how often they occurred. The patient cohort with pre-activation of zero minutes could not have a time-out, which theoretically would lead to worse trauma team performance, but as we do not know how often or efficiently time-outs happened in the rest of the cohort, we cannot comment on it. Moreover, inter-rater reliability was not measured for the study's video reviewers, although they met regularly every week for quality assurance and rectified discrepancies in data collection on a regular basis.

Another limitation is that since this is an exploratory study at a single center, it limits the generalizability as other hospitals may be set up differently and have different personnel and resources available, which may also vary depending on the time of day, weekday, and even month. Due to the nature of an exploratory study, we are also unable to establish cause and effect between pre-activation times and TCCAs. Although our patient cohort had a relatively low rate of needing chest tubes, thoracotomies, or central lines, competing interests within the team may have influenced the timely performance of certain tasks, a limitation we attempted to mitigate by including in our analysis 11 different critical actions. Additionally, our TCCAs are 'intubation heavy', so in populations that rarely intubate, other criteria may be more appropriate to measure performance. Moreover, certain confounding factors from EMS reports to medical control could affect the timeliness of activation and the trauma team's sense of urgency to complete certain tasks. We do not have a good understanding of these 'unmeasured' metrics or their contribution to the TCCAs. We also did not have the data on time from injury, which may affect results as patients with the same objective injury severity score may present markedly different to the hospital if transport time (ie, time from injury) is different. We did include the injury severity scores of our study population in table 2. Analysis of the trauma patients transferred in showed that they made up 30% of cases (142/466). Within the short pre-activation group, 37% (124/338) were transferred patients while in mid and long pre-activation groups, transferred patients made up only 14% (12/87) and 15% (6/41), respectively (table 2). For the transferred in patients, it seems that mid to long pre-activation was less frequent, perhaps because the trauma team has more information on the patient, which may also affect TCCAs.

The shorter TCCAs may also be explained by the time of trauma attending response, as the team leader has an oversized impact on the performance of the team, for although both long and mid pre-activation had a trauma attending response time of 0 min, the short pre-activation group had a trauma attending response time of 3 min. These additional minutes could cause delays in performing critical actions. Lastly, since intubation contributed a significant portion of the TCCAs, it is important to mention that the intubation rate for short pre-activations was lower (26%) than for mid (31%) or long (29%) pre-activations. This may have affected outcomes.

CONCLUSION

In our exploratory study, we found that there is an optimal pre-activation time to minimize TCCAs. This period was between 4 and 7 min before patient arrival at our center. Future studies will attempt to elucidate if this same Goldilocks timeframe shows highest efficiency in other trauma centers and to identify which specific events are being affected by pre-arrival preparation.

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REFERENCES

1. Lillebo B, Seim A, Vinjevoll OP, Uleberg O. What is optimal timing for trauma team alerts? A retrospective observational study of alert timing effects on the initial management of trauma patients. *J Multidiscip Healthc* 2012;5:207–13.
2. Wang CJ, Yen ST, Huang SF, Hsu SC, Ying JC, Shan YS. Effectiveness of trauma team on medical resource utilization and quality of care for patients with major trauma. *BMC Health Serv Res* 2017;17:505.
3. James MK, Clarke LA, Simpson RM, Noto AJ, Sclair JR, Doughlin GK, Lee S-W. Accuracy of pre-hospital trauma notification calls. *Am J Emerg Med* 2019;37:620–6.
4. Elm E von, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. Strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *BMJ* 2007;335:806–8.
5. Virtanen P, Gommers R, Oliphant TE, Haberland M, Reddy T, Cournapeau D, Burovski E, Peterson P, Weckesser W, Bright J, *et al*. SciPy 1.0: fundamental algorithms for scientific computing in Python. *Nat Methods* 2020;17:261–72.
6. McKinney W. Data structures for statistical computing in python. Proceedings of the 9th Python in Science Conference (Vol. 445, No. 1, pp. 51-56); 2010,
7. Spering C, Roessler M, Kurlemann T, Dresing K, Stürmer KM, Lehmann W, Sehmisch S. Optimierte Ressourcenmobilisation und Versorgungsqualität Schwerstverletzter durch eine strukturierte Schockraumalarmierung [Optimized resource mobilization and quality of treatment of severely injured patients through a structured trauma room alarm system]. *Unfallchir* 2018;121:893–900.
8. Holcomb JB, Tilley BC, Baraniuk S, Fox EE, Wade CE, Podbielski JM, del Junco DJ, Brasel KJ, Bulger EM, Callcut RA, *et al*. Transfusion of plasma, platelets, and red blood cells in a 1:1:1 vs a 1:1:2 ratio and mortality in patients with severe trauma: the PROPPR randomized clinical trial. *JAMA* 2015;313:471–82.
9. Jansen JO, Hudson J, Cochran C, MacLennan G, Lendrum R, Sadek S, Gillies K, Cotton S, Kennedy C, Boyers D, *et al*. Emergency Department Resuscitative Endovascular Balloon Occlusion of the Aorta in Trauma Patients With Exsanguinating Hemorrhage: The UK-REBOA Randomized Clinical Trial. *JAMA* 2023;330:1862–71.
10. Ruelas OS, Tschautscher CF, Lohse CM, Sztajnkrycer MD. Analysis of Prehospital Scene Times and Interventions on Mortality Outcomes in a National Cohort of Penetrating and Blunt Trauma Patients. *Prehosp Emerg Care* 2018;22:691–7.
11. Hsieh S-L, Hsiao C-H, Chiang W-C, Shin SD, Jamaluddin SF, Son DN, Hong KJ, Jen-Tang S, Tsai W, Chien D-K, *et al*. Association between the time to definitive care and trauma patient outcomes: every minute in the golden hour matters. *Eur J Trauma Emerg Surg* 2022;48:2709–16.
12. Berkeveld E, Azijli K, Bloemers FW, Giannakópoulos GF. The effect of a clock's presence on trauma resuscitation times in a Dutch level-1 trauma center: a pre-post cohort analysis. *Eur J Trauma Emerg Surg* 2024;50:489–96.
13. Kelleher DC, Jagadeesh Chandra Bose RP, Waterhouse LJ, Carter EA, Burd RS. Effect of a checklist on advanced trauma life support workflow deviations during trauma resuscitations without pre-arrival notification. *J Am Coll Surg* 2014;218:459–66.
14. van Maarseveen OEC, Ham WHW, van de Ven NLM, Saris TFF, Leenen LPH. Effects of the application of a checklist during trauma resuscitations on ATLS adherence, team performance, and patient-related outcomes: a systematic review. *Eur J Trauma Emerg Surg* 2020;46:65–72.
15. Bedard AF, Mata LV, Dymond C, Moreira F, Dixon J, Schauer SG, Ginde AA, Bebarta V, Moore EE, Mould-Millman N-K. A scoping review of worldwide studies evaluating the effects of prehospital time on trauma outcomes. *Int J Emerg Med* 2020;13:64.
16. Durr K, Ho M, Lebreton M, Goltz D, Nemnom MJ, Perry J. Evaluating the impact of pre-hospital trauma team activation criteria. *CJEM* 2023;25:976–83.
17. Ahmed OZ, Yang S, Farneth RA, Sarcevic A, Marsic I, Burd RS. Association Between Prearrival Notification Time and Advanced Trauma Life Support Protocol Adherence. *J Surg Res* 2019;242:231–8.