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Sensitivity and specificity of trauma team activation protocol criteria in an Italian trauma center: A retrospective observational study

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ABSTRACT

Background: The trauma team (TT) model could reduce mortality, morbidity, and duration of hospital stay, costs, and complications. To avoid over- or undertriage for trauma team activation, robust criteria have to be chosen.

Objective: This study aimed to evaluate the sensitivity and specificity of a TT activation protocol for major trauma patients to predict the need for emergency treatment.

Methods: A retrospective observational study was carried out in the Emergency Department (ED) of a major Italian trauma center. Patients with trauma or burns who accessed the ED in 2015 with a triage red or yellow priority treatment code were included, while pediatric patients were excluded. Sensitivity, specificity and positive predictive values were calculated for each TT activation criteria and the aggregated criteria.

Results: Data from 240 patients were collected: 40.42% of patients had a congruent triage while 50% were overtriaged and 9.58% undertriaged. A correct triage led to a lower hospital stay ($p < 0.01$), while undertriage was not associated with patients' death ($p = 0.16$). All criteria had a specificity higher than 95%, a total sensitivity of 80.83% and a total positive predictive value of 43.49%.

Conclusion: This study highlighted that the TT activation criteria had high specificity and sensitivity, while the positive predictive value of the criteria was lower. Mechanisms of injury criteria were less specific and sensitive in detecting the TT activation correctly. As nurses play a pivotal role in the triage of traumatized patients and the TT, reduction of under- and overtriage is essential to improve the patients' health outcome.

1. Introduction

Major trauma is the sixth cause of death worldwide, causing annually 10% of all deaths, and is the fifth major cause of significant disability [3]. In particular, it is the second cause of death in people aged between 15 and 49 [20]. To give optimal care to traumatized patients accessing the Emergency Departments (EDs), the adoption of a trauma team (TT), consisting of a multidisciplinary team, is a widely recognized standard of care [4]. This model is therefore essential to ensure the best results in terms of mortality, morbidity, duration of hospital stay, costs, and complications [26,32]. A trauma team (TT) is a group of health professionals, physician, nurses and support staff whose primary responsibility is to manage severely injured patients in a multidisciplinary manner in the ED. Nurses play a fundamental role in the trauma team, and the presence of a nurse as a team leader is effective in increasing the team members' communication [10].

To correctly activate the TT, an out-of-hospital triage has to take place to maximize the TT efficacy. Activation protocols are mainly based on pre-hospital information provided by out-of-hospital emergency medical services, which have the purpose of already starting a multidisciplinary treatment in the phases preceding entry into the ED. The early activation of a dedicated team reduces the time to treatment and limits the waste of resources caused by unnecessary alerts of the team [12]. In the literature [27,30], different alert criteria can be found, but they are conventionally divided into three groups: physiological, anatomical and mechanism of injury [4]. Optimal timing for TT alert affects the initial management of traumatized patients, as it could improve team preparation and performance while also limiting adverse

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consequences in patients' care [18].

The activation of the TT for minor or moderate injuries may lead to an overtriage [11]. Overtriage is common [30], and could result in a resource problem, making some health professionals unavailable in other essential hospital activities. By contrast, undertriage can seriously compromise the traumatized patients' health outcomes [4]. One of the most common indexes used to evaluate the severity of anatomic injuries is the Injury Severity Score (ISS) [5]; this score could be used to evaluate over- or undertriage of trauma patients. Trauma team activation could be considered as overtriage when the ISS is ≤15 or when the patient has not undergone an emergency procedure, while undertriage would be the group of patients accepted without trauma team activation, despite an ISS > 15 or when the patient has received an emergency procedure [11].

To avoid over- or undertriage for trauma team activation, criteria have to have maximum sensitivity to correctly identify high-risk patients, while at the same time minimize overtriage of patients at low or moderate risk. In defining activation criteria, it is necessary to consider the characteristics of the served population, the resources available, and the organization of each structure [4]. Out-of-hospital triage, using robust activation criteria is pivotal for optimally treating patients as soon as they arrive in the ED [28]. In addition, triage performed by ED registered nurse specialized in trauma care could increase triage accuracy [15]. Triage nurse personal skills and characteristics seem not to influence the quality of triage [14], therefore, nurse clinical judgment combined with clinical scores could be the best way to prioritize admission to ED and TT activation [7].

Thus, this study aimed to evaluate the sensitivity and specificity of a TT activation criteria protocol for major trauma patients performed by trauma care nurses in an Italian University Hospital.

2. Methods

A retrospective observational study was carried out in the ED of the trauma center of a major Italian University Hospital. This University Hospital is a Magnet tertiary care teaching hospital in the north-west part of Italy. It comprises four EDs: a generalist ED, a pediatric ED, an obstetric-gynecological ED and the ED of the trauma center. This last ED every year treats approximately 300 red priority treatment, and 700 yellow priority treatment trauma patients excluding people with a hip fracture or a minor trauma. The Italian priority triage system is divided into four priority codes as illustrated in Box 1.

Box 1. Italian priority triage system

RED	People with extremely critical vital functions and need for immediate access to care.
YELLOW	People with moderately critical vital functions, presence of risk of deterioration, and need for being evaluated between 10 and 20 min.
GREEN	Apparently stable patient with deferrable treatment, and need for being evaluated in 60 min.
WHITE	Apparently stable patient, and need for being evaluated in 120 min.

In 2014, the trauma center in this study updated their protocol for the treatment of major trauma. This protocol included the creation of a TT to manage this emergency. The alert criteria used by the TT were adapted to the local context and the hospital resources. Activation criteria are shown in Table 1. This observational study has been reported according to the strengthening the reporting of observational studies in epidemiology (STROBE) guidelines [31].

2.1. Population

Patients with trauma or burns who accessed the ED, between 1 Jan and 31 Dec 2015 with a triage red or yellow priority treatment code were included. This was the first full year of available data after the TT activation protocol implementation. Patients were excluded if they were aged under 16 years old, were transferred from other hospitals or hospitalization units more than 24 h after injury, had a red or yellow priority treatment code but were not affected by a traumatic pathology, or if it was not possible to retrieve data due to the absence of clinical records in the hospital registry. To estimate the sensitivity and specificity of the TT activation criteria, patients were finally included if they had the trauma team activation or they received one of the following emergency procedures indicating a severe physiologic impairment, as defined by Dehli et al. [11]:

- endotracheal intubation;
- thoracic drainage insertion;
- hemostatic surgery of the abdomen;
- hemostatic surgery in the pelvis with packing;
- thoracotomy;
- primary stabilization of fractures with external fixator;
- blood transfusion;
- cardio-pulmonary resuscitation;
- escharotomy;
- tracheotomy;
- external containment of the pelvis (T-POD positioning);
- external fixation of the pelvis;
- peritoneal lavage;
- pericardiocentesis.

Other procedures, such as surgical airway, were not considered as not commonly used in specialized trauma centers.

Table 1
Trauma Team activation criteria.

Activation Criteria	
Physiological variables	GCS < 14 RR < 10 or > 29 breaths/min Systolic BP < 90 mmHg
Anatomical variables	Penetrating trauma Flail chest Fracture of the pelvis Fracture > 2 proximal long bones Paralysis Traumatic amputation above wrist/ankle
Type of trauma	Car accident Ejection from car Co-passenger death Pedestrian hit by motor vehicle Vehicle overturned High speed impact Extrication time > 20 min Cyclist hit by motor vehicle Fall from > 5 m Electrocution Pregnancy > 16 weeks Burn > 20% Burn caused by inhalation

GCS = Glasgow Coma Scale; RR = respiratory rate; BP = blood pressure.

2.2. Data collection

Data were collected from the hospital registry. A specific data extraction form was built to collect the data. The data extraction form was pilot tested beforehand, and a nurse with a master degree in Nursing was trained to extract data (CM). 25% of data extracted were then randomly checked by a second independent researcher (SL) for accuracy. An almost perfect agreement between data extracted was found ($k = 0.91$, $p < 0.01$) [19]. Any disagreement was solved through discussion until 100% of the data extraction agreement was reached. Data collection included demographic data, duration of hospital stay, the admission to another ward from ED and mortality. In particular, the TT

activation criteria were retrieved from the integrated trauma card present with all the patients admitted with a traumatic injury. This card reports the activation criteria for three categories: physiological, anatomical and mechanism of injury (Table 1). Overtriage was defined as if the ISS was ≤ 15 or if the patient had not undergone an emergency procedure despite the TT activation. Undertriage was defined as if a patient was admitted without TT activation, despite an ISS > 15 or when he or she received an emergency procedure [11].

2.3. Data analysis

The general characteristics of the sample were presented with absolute numbers and percentages for categorical variables, while for continuous variables means and standard deviation were calculated. Sensitivity, specificity, and positive predictive values were calculated for each TT activation criterion and the aggregated physiological, anatomical, and type of trauma criteria (Table 1), as well as for the sum of all the criteria. The proportions of sensitivity and specificity were compared using Z-test for proportions. To examine the association between variables, the *t*-test for continuous variables and the chi-square for categorical variables were used. Missing data were analyzed with pairwise deletion. All tests were conducted two-tailed and a p-value < 0.05 was considered statistically significant in this study. The analyses were conducted using the SPSS Statistic software (IBM Corp. Released 2012. IBM SPSS Statistics for Apple Macintosh OSX, Version 21.0. Armonk, NY: IBM Corp.).

2.4. Ethics

The study was approved and authorized by the Health Directorate of Centro Traumatologico Ortopedico of Turin. This research followed the Code of Ethics of the World Medical Association. Data consultation took place in a protected place ensuring maximum confidentiality of personal data according to the best practice in clinical research ethics. All personal data were anonymized attributing an alphanumeric code not directly attributable to the patient and treated as confidential.

3. Results

Data from 240 patients were collected: 97 patients (40.42%) had a congruent triage while 120 (50%) were overtriaged and 23 (9.58%) undertriaged (Fig. 1). The majority of the sample were males (78.51%) with a mean age of 47.61 (SD ± 19.22), being hospitalized for a mean length of stay of 21.08 (SD ± 18.46) days. After access and treatment, 151 patients (62.92%) were transferred to inpatient settings, 65 patients (27.08%) to an intensive care unit, 4 (1.67%) were discharged directly to their home, and 20 patients (8.33%) died in the ED. The total deaths (ED + inpatients after access) were 36 (15%).

In total, there were 217 TT activations, of which 120 (55.23%) were without the use of emergency procedures and 97 (40.42%) with their implementation. A total of 23 (9.58%) patients had undergone emergency procedures even though they were not carried out following TT activation. The most used physiological variable to activate TT was *the Glasgow Coma Scale (GCS) < 14*. The most common mechanism of injury variable was *a car accident*, while the anatomical variable was *a fracture of the pelvis*. When analyzing patients in undertriage, the mean age increased to 53.61 years (SD ± 21.10), the mean length of stay was reduced to 16.17 days (SD ± 13.85), and at least one patient underestimated out of four (26.09%) died. For overtriage patients, the proportion of patients who died during hospital admission was 8.33%. Similarly, there was a reduction in the mean age (45.78 years, SD ± 19.31) and in the mean length of stay (19.08 days, SD ± 15.82). Of the 97 patients correctly assessed during the TT alert, 20.62% died, and the mean length of stay was 24.28 days (SD ± 21.68). From the analyses, a statistically significant association emerged between the correct activation of the TT and the days of hospitalization ($p < 0.01$). The deaths were not statistically associated with the undertriage ($p = 0.16$).

The analysis of the specificity of the activation criteria showed that all the criteria had very high specificity, with a score higher than 95%, namely the criteria were able to correctly identify patients who did not need the TT (Table 2). There was a considerable differentiation in the sensitivity results, even though the total sensitivity was high (80.83%) (Table 2). The total positive predictive value of the criteria was 43.49%. When the positive predictive value for a single criterion was calculated, it highlighted that the most predictive category of criteria was the anatomical category, while the least predictive was the mechanism of injury. The predictive value of the *respiratory rate* and the *pregnancy > 16 weeks* variables could not be calculated because they were never indicated as a criterion for alerting the TT. The positive predictive values for each criterion are shown in Table 2. A statistically significant different proportion of sensitivity and specificity between the mechanism of injury and anatomical and physiological criteria was found ($p < 0.05$).

4. Discussion

This study aimed to evaluate the sensitivity and specificity of TT activation criteria. The results of this study highlighted that the criteria had a high specificity and sensitivity, while the positive predictive value of the criteria was lower.

A delayed TT activation is linked to older patients [21]. Being older could underestimate TT activation and could lead to a limitation of care. The activation criteria adopted were not able to detect trauma derived from low-energy injuries, such as falls on the ground [6]. Furthermore, vital signs in people aged 65 years and over are less reliable in predicting the severity of trauma [17]. Also, according to some studies [1,2,23], the mortality rate of patients with trauma increases with increasing age. In particular, the study by Clegg, Young, Iliffe, Rikkert, and Rockwood [9] emphasizes that the geriatric trauma population have an increased mortality risk compared to younger patients. This is confirmed in our study, with a mortality rate for patients over 65 years (n = 53) of 41.51%, while the mortality rate for patients under the age of 65 (n = 187) was 7.49%. Specific activation criteria for older adults could be adopted to better evaluate TT activation and improve patients' outcomes, in particular, mortality.

The results of this study confirm that males are more subject to major traumas than females [11]. Moreover, our population presented a lower age compared with the literature [11,30]. This could be due to the exclusion criteria of this study, which did not include the pediatric population.

The results of this study were also comparable when looking at undertriage, while the overtriage was higher than in other studies [24]. Even if overtriage could be useful in centers not specialized in trauma care, it is expected to be lower in the ED of trauma centers. Moreover, this could be due to an increase in defensive medicine in the ED. Overtriage could result in more costs and undue practices in the attempt to avoid legal issues arising from the triage [8].

The total sensitivity of the criteria was similar to other studies [11]. In particular, the frequency of use of the 16 activation criteria of the TT was comparable in patients who have received emergency procedures. In this study, the mechanism of injury emerged as the most important activation criteria, limiting the physiological criteria use. When looking at the reports of the out-of-hospital emergency medical services, it emerged that the physiological criteria should have been considered 117 times, unlike the 66 times expressed on the TT activation card. This could lead to negative consequences such as a waste of time and resources and, most important, to disaffection with the TT activation protocol as professionals clearly perceive the high rate of overtriage.

The results of our study about predictive values partially overlap with those of other studies in the literature [29]. Physiological criteria are widely recognized as the most critical criteria for TT activation

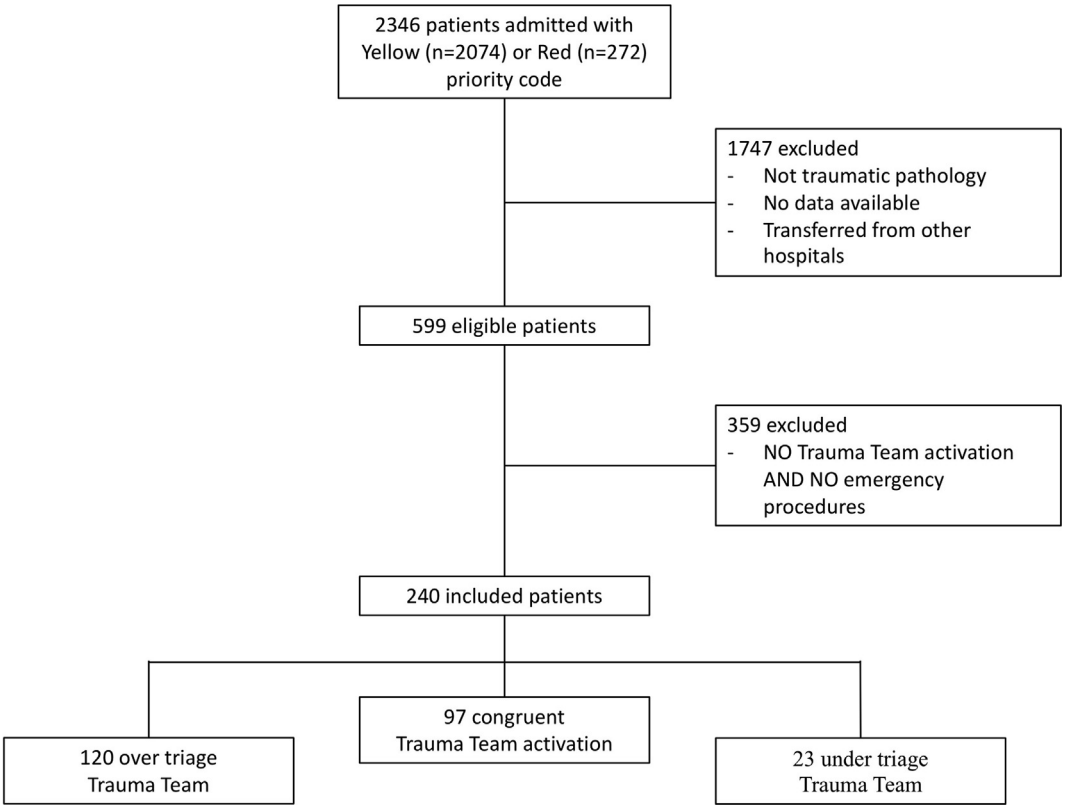

Fig. 1. Study patients flow-chart.

Table 2
Sensitivity, specificity and positive predicted values of the Trauma Team activation criteria.

Activation criteria	Sensibility % (CI)	Specificity % (CI)	Positive Predictive Value % (CI)
Physiological variables	58.93 (44.98–71.90)	94.73 (92.56–96.41)	52.39 (39.41–65.12)
GCS < 14	53.06 (38.27–67.47)	95.91 (93.92–97.39)	53.06 (38.27–67.47)
RR < 10 or > 29 breaths/min	0.00 (0.00–14.82)	100.00 (99.32–100.00)	–
Systolic BP < 90 mm Hg	23.33 (9.93–42.28)	98.72 (97.38–99.48)	50.00 (23.04–76.96)
Anatomical variables	54.90 (40.34–68.87)	96.25 (94.32–97.66)	57.14 (42.21–71.18)
Penetrating trauma	4.17 (0.11–21.12)	99.81 (98.97–100.00)	50.00 (1.26–98.74)
Flail chest	14.81 (4.19–33.73)	99.08 (97.87–99.70)	44.44 (13.70–78.80)
Fracture of the pelvis	30.30 (15.59–48.71)	99.45 (98.39–99.89)	76.92 (46.19–94.96)
Fracture > 2 proximal long bones	14.81 (4.19–33.73)	98.54 (97.14–99.37)	33.33 (9.92–65.11)
Paralysis	8.00 (0.98–26.03)	99.81 (98.97–100.00)	66.67 (9.43–99.16)
Traumatic amputation above wrist/ankle	23.33 (9.93–42.28)	99.45 (98.39–99.89)	70.00 (34.75–93.33)
Type of trauma	84.97 (78.30–90.23)	83.18 (80.07–85.98)	48.34 (41.43–55.30)
Car accident	58.93 (44.98–71.90)	95.06 (92.94–96.69)	54.10 (40.85–66.94)
Ejection from car	11.54 (2.45–30.15)	100.00 (99.32–100.00)	100.00 (29.24–100.00)
Co-passenger death	8.00 (0.98–26.03)	99.63 (98.67–99.96)	50.00 (6.76–93.24)
Pedestrian hit by motor vehicle	36.11 (20.82–53.78)	98.36 (96.91–99.25)	59.09 (36.35–79.29)
Motorcycle accident	39.47 (24.04–56.61)	96.25 (94.32–97.66)	41.67 (25.51–59.24)
Vehicle overturned	11.54 (2.45–30.15)	99.26 (98.12–99.80)	42.86 (9.90–81.59)
High speed impact	23.33 (9.93–42.28)	99.26 (98.12–99.80)	63.64 (30.79–89.07)
Extrication time > 20 min	14.81 (4.19–33.73)	99.81 (98.97–100.00)	80.00 (28.36–99.49)
Cyclist hit by motor vehicle	14.81 (4.19–33.73)	96.41 (93.30–98.35)	30.77 (9.09–61.43)
Fall from > 5 m	41.03 (25.57–57.90)	95.57 (93.53–97.11)	39.02 (24.20–55.50)
Electrocution	4.17 (0.11–21.12)	99.81 (98.97–100.00)	50.00 (1.26–98.74)
Pregnancy > 16 weeks	0.00 (0.00–14.82)	100.00 (99.32–100.00)	–
Burn > 20%	8.00 (0.98–26.03)	99.26 (98.12–99.80)	33.33 (4.33–77.72)
Burn caused by inhalation	0.00 (0.00–14.82)	99.81 (98.97–100.00)	0.00 (0.00–97.50)
TOTAL	80.83 (72.64–87.44)	81.17 (77.99–84.08)	43.49 (37.07–50.49)

GCS = Glasgow Coma Scale; RR = respiratory rate; BP = blood pressure.

[16]. These confirm our results about the fact that the mechanism of injury is the least predictive criterion and should not be considered alone for TT activation [25]. Moreover, some mechanisms of injury appeared similar to other criteria. Further efforts should be made to have a more explicit conceptualization of the type of criteria and their combination. This phenomenon should be further investigated to understand whether, for example in a mountain context, like the one in this study, the introduction and validation of other criteria such as skiing trauma or exposure to freezing temperatures are necessary [22]. Mechanism of injury criteria also had the lowest rate of specificity. This

may be since there may be difficulties in the communication chain between the citizen, the out-of-hospital emergency medical services and the ED. In future research, it would be interesting to analyze the communication dynamics between the out-of-hospital emergency medical services and the ED on the determination and evaluation of the TT activation criteria. Moreover, the introduction of context-specific criteria, such as criteria for older adults or criteria for a specific context (e.g., mountainous areas) should be considered and tested. Also, a computer-aided, decision support could be used to improve errors in patients' allocation and adherence to triage algorithms [13].

4.1. Limitations

The study presented some limitations mainly related to its retrospective design. Retrospective data collection may lead to biases. For this reason, in addition to the hospital registry, the microfilm of medical records was hand-searched to include all the major trauma patients admitted to the hospital. Secondly, this is a single-center study, and the results may not be generalizable to other contexts with different trauma epidemiology.

Furthermore, the hospital in the study does not admit obstetric and gynecological patients as they refer to a specialist ED. This is the reason why the one *pregnancy > 16 weeks* criterion was never present in our database. This could have limited our analyses. Lastly, the relatively small sample size could have limited the generalizability of the results. Despite these limits, this is the first study assessing the TT activation criteria from the nurses' perspectives.

5. Conclusions

This study highlighted that the TT activation criteria used had high specificity and sensitivity, while the positive predictive value of the criteria was lower. The use of the mechanism of injury criteria alone should be avoided, as they were less specific and sensitive in determining the TT activation. Better identification of the criteria used to activate the TT can lead to a more robust patient evaluation with a consequent reduction of under- and overtriage and with an improvement in patient health outcomes. As nurses play a pivotal role in the triage of traumatized patients and the TT, an awareness of which criteria should be considered is therefore essential.

Conflict of interest

None.

Ethics

This research followed the Code of Ethics of the World Medical Association.

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