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ORIGINAL ARTICLE

Trauma patients centralization for the mechanism of trauma: old questions without answers

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Abstract
Introduction Centralization of trauma patients has become the standard of care. Unfortunately, overtriage can overcome the capability of Trauma Centres. This study aims to analyse the association of different mechanisms of injury with severe or major trauma defined as Injury Severity Score (ISS) greater than 15 and an estimation of overtriage upon our Trauma Centre.
Methods A retrospective review of our prospective database was undertaken from March 2014 to August 2016. Univariate and multivariable logistic regression models were used to estimate the association between covariates (gender, age, and mechanisms of injury) and the risk of major trauma.
Results The trauma team (TT) treated 1575 patients: among the 1359 (86%) were triaged only because of dynamics or mechanism of trauma. Overtriage according to an ISS < 15, was 74.6% on all trauma team activation (TTA) and 83.2% among the TTA prompted by the mechanism of injury. Patients aged 56–70 years had an 87% higher risk of having a major trauma than younger patients (OR 1.87, 95% CI 1.29–2.71) while for patients aged more than 71 years OR was 3.45, 95% CI 2.31–5.15. Car head-on collision (OR 2.50, 95% CI 1.27–4.92), intentional falls (OR 5.61, 95% CI 2.43–12.97), motorbike crash (OR 1.67, 95% CI 1.06–2.65) and pedestrian impact (OR 2.68, 95% CI 1.51–4.74) were significantly associated with a higher risk of major trauma in a multivariate analysis.
Conclusions Significant association with major trauma was demonstrated in the multivariate analysis of different mechanisms of trauma in patients triaged only for dynamics. A revision of our field triage protocol with a prospective validation is needed to improve overtriage that is above the suggested limits.

Keywords Trauma centres · Injury Severity Score · Triage · Multiple trauma · Mechanism of injury

Introduction

Traumatic injuries usually ask for demanding organisation both for time-related needs and a comprehensive and immediate multidisciplinary approach to reach acceptable outcomes [1, 2]. Moreover, regionalisation of trauma care has proved better results regarding mortality [3]. In Lombardia Region, Italy, a trauma system was established in October 2012 [4], aiming at the creation of six Level I Trauma centres, connected with several other hospitals as lower level centres. No standard monitoring or regulations for the managing of data exist in Italy, as well as in Lombardia in the north part of the State. Lombardia is a 10 million inhabitants region and has four Emergency Medical System (EMS) control rooms. Bergamo province is in the middle of the region and accounts for a 1.1 million population served by the Papa Giovanni XXIII Hospital, the only Level I-II Trauma Centre with neurosurgery, which is the referral for unstable patients also for the Sondrio province (further 181,000 inhabitants), and it holds one of the EMS control rooms. At the beginning of our experience overtriage was the main concern of the field triage protocol because it could wear out the Trauma Team and the Emergency Department. Moreover, trauma care has

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a well-renowned impact on cost and the National Health System [5, 6]. Because the vast majority of Trauma Team Activation (TTA) comes from the mechanism of injury (or dynamics), rather than measured vital signs or from specific anatomic lesions [12], this could be considered the first cause of overtriage [7]. On the other hand, undertriage is far more dangerous for the safety of patients to be sent to Trauma Centres because undertriage may result in preventable mortality or morbidity from delays in definitive care. Overtriage is a matter of human and technological resources, and although it has minimal adverse medical consequences for the patient, it results in excessive costs and burden for higher-level trauma centres in the routine care of injured patients [8]. We published a preliminary report on this subject [9], and this is the completion of the analysis of all available data. Aims of this study are, therefore: (1) to estimate the rate of overtriage and undertriage upon our Trauma Centre and (2) to investigate the association between different mechanisms of injury and the risk of major trauma in a subgroup of TTA driven by the trauma dynamic.

1	**Vital signs**	Glasgow Coma Scale < 13	
		Systolic Blood Pressure < 90 mm Hg	
		Respiratory Rate < 10 / min. or > 29 / min.	
2	**Lesions**	Penetrating	
		Flail Chest	
		2 or more proximal fractured long bones	
		Crushing, degloving of limb	
		Amputation	
		Pelvic Fracture	
		Open or depressed skull fracture	
		Paralysis	
		Trauma associated burns	
		Burns > 10% of body surface	
3	**Dynamics**	Fall	
		Adults > 3 m (1 floor)	
		High speed vehicle impact:	
		Ejection	
		Head-on collision	
		Off road	
		Fixed obstacle (wall, tree...) or lorry, bus	
		Roll-over	
		Simple rear-end collision	
		Bike or motobike	
		Pedestrian, high energy	

Fig. 1 Field triage protocol for trauma team activation

Materials and methods

This is a retrospective study based on a prospective registry of patients presenting to Papa Giovanni XXIII Hospital in Bergamo. One of the authors (SM) supervised the collection of all data. The registry was established in March 2014 and includes all patients managed by the Trauma Team (TT) which is prompted at a unique level of activation by the Emergency Medical System or in the Emergency Department (ED) Triage Room according to a shared field triage protocol (Fig. 1). According to this protocol, TTA is driven by the following criteria: (1) alteration of vital signs of patients, (2) presence of clinically evident lesions or (3) mechanism of injury.

No data are available for patients that did not prompt TTA. Anatomical injury severity was expressed by the Injury Severity Score (ISS), and major trauma is commonly identified by an ISS greater than 15.

Different definitions of overtriage were compared to evaluate the degree of eventually excessive TTA for dynamics in our Centre: (1) patients with an ISS < 15; (2) patients with a length of stay < 48 h without any surgical intervention nor ICU admission, [10–12] or (3) patients discharged from the ED. Undertriage was defined as (1) the percentage of patients transferred from other hospitals or ED within 24 h from the event of trauma and who had an admission longer than 2 days or a surgical treatment or (2) the percentage of patients with ISS > 15 transferred from other hospitals or ED within 24 h from the index event [12].

Statistical analysis

The rate of overtriage and undertriage was calculated for TTA that was prompted only by the mechanism of injury, using the above definition and expressed as a proportion. This is because; an assumption was made that only patients without altered vital signs or anatomic lesions, as in Fig. 1, could be transported to non-Level I Trauma Centre such as Papa Giovanni XXIII.

For the subsequent analyses, only TTA for the mechanism of injury was considered, and the characteristics of patients were reported.

Continuous variables were expressed as median and Interquartile Range (IQR), while categorical variables were expressed as proportions. Mann–Whitney *U* test and the Chi-square test (or Fisher's exact test, when appropriate) were used to compare continuous and categorical variables, respectively. Univariate and multivariable logistic regression models were used to estimate the unadjusted/adjusted Odds Ratios (ORs) and the corresponding 95% confidence intervals (CIs) for the association between covariates (gender, age and mechanisms of injury) and the risk of major trauma.

For all tested hypotheses Two-tailed *p* values less than 0.05 were significant. Analyses were performed using STATA software, release 13 (Stata Corp LP, College Station TX, USA).

Results

Between March 2014 and October 2016, the TT treated 1575 patients. Of these, 26 TTA (2%) by evident clinical lesions, 190 TTA (12%) were prompted by altered vital signs, and 1359 (86%) by dynamics or mechanism of injury. Mortality among all TTA was 4.3% and 1% among TTA for dynamics.

Rate of overtriage and undertriage

Overtriage rates were: (1) according to an ISS < 15 was 83.2%; (2) according to ACS-COT definition was 53.7% and (3) according to the discharge rate from the ED was 47.6%.

Undertriage was 5.8% considering all patients transported to Papa Giovanni XXIII Hospital for the mechanism of trauma (median ISS 8, Interquartile Range, IR 4–9) and 1% considering patients with ISS > 15 (median ISS 17, IR 16–25).

Characteristics of TTA prompted only by the mechanisms of injury

Patients' characteristics related to the TTA prompted by the mechanism of injury are reported in Table 1. Male/female ratio was 2.66 (988/371), median age was 44.0 years old (IQR 29.0–57.0). The mechanisms of injury included: car crash (35.9%), motorbike crash (25.0%), falls (17.6%), bike collision (10.0%), pedestrian hit by a motor vehicle (7.9%), and other mechanisms (3.5%). Median ISS was 5.0 (2.0–13.0) while 214 (15.9%) patients reported a major trauma (ISS > 15).

Table 1 Characteristics of patients among the TTA for dynamics

Characteristics of patients	*N* (total 1359)
Gender	
Female	371 (27.3%)
Male	988 (72.7%)
Age	
Median (IQR)	44.0 (29.0–57.0)
Age distribution	
18–55	986 (72.6%)
56–70	231 (17.0%)
71 +	142 (10.4%)
Mechanism of injury	
Car crash (all mechanisms)	488 (35.9%)
Motorbike crash	340 (25.0%)
Fall	239 (17.6%)
Bike collision	136 (10.0%)
Pedestrian hit by vehicle	108 (7.9%)
Other	48 (3.5%)
Injury Severity Score	
Median (IQR)	5.0 (2.0–13.0)
Major trauma (ISS > 15)	
No	1,133 (84.1%)
Yes	214 (15.9%)

The characteristics of patients with and without major trauma are reported in Table 2. Major trauma patients are significantly older than non-major trauma patients (median age 54.0 vs 42.0, $p = 0.00$) while no difference in gender was observed ($p = 0.072$). The proportion of major traumas among the different mechanisms of injury was significantly different ($p = 0.039$). Among all the different mechanisms of injury, the car crash was the most frequent one, accounting for the 28.0% of major trauma patients and the 37.2% of non-major trauma patients. Motorbike crash represented the 25.7% of major trauma patients (16.9% of non-major trauma group). Moreover, among patients with major trauma due to a car crash, 25% happened because of head-on collisions (12.4% in non-major trauma group). Falls represented the 21.5% of major trauma patients (16.9% in non-major trauma group), and pedestrians are 11.7% in major trauma group (vs 7.1% in non-major trauma group), while bike collision was the least frequent mechanism of injury among patients with major trauma (8.9%).

Association between the mechanisms of injury and the risk of major trauma

Table 3 reports the unadjusted estimates of the ORs (and the corresponding 95% CIs) for the association between the considered covariates and the risk of major trauma. A significant trend toward growing risk of major trauma with increasing age was found ($p < 0.0001$). Patients aged 56–70 years had an 87% higher risk than younger patients (OR 1.87, 95% Confidential Interval (CI) 1.29–2.71) while patients aged more than 71 years had a risk of major trauma of over three times higher (OR 3.45, 95% CI 2.31–5.15). Compared with unknown mechanisms, car head-on collision (OR 2.50, 95% CI 1.27–4.92), intentional falls (OR 5.61, 95% CI 2.43–12.97), motorbike crash (OR 1.67, 95% CI 1.06–2.65) and pedestrian impact (OR 2.68, 95% CI 1.51–4.74) were significantly associated with a higher risk of major trauma (Table 3, left column). By adjusting the estimates for the effect of age and sex, slightly lower (but overlapping) effects were found. Car head-on collision, intentional falls, motorbike crash, and pedestrian impact, had a significant and independent effect on the increased risk of major trauma (Table 3, right column).

Discussion

Field triage, undertriage and overtriage have always been the mainstay in the setting of a mature trauma system [12].

Table 2 Characteristics of patients with and without major trauma among the TTA for dynamics

Characteristics	Major trauma (ISS > 15)		*p***
	No (*N* = 1.133)	Yes (*N* = 214)	
Gender			
F	322 (28.4%)	48 (22.4%)	0.072
M	811 (71.6%)	166 (77.6%)	
Age			
Median (IQR)	42.0 (28.0–55.0)	54.0 (39.0–70.0)	< 0.0001
Age distribution			
18–55	855 (75.5%)	120 (56.1%)	< 0.0001
56–70	183 (16.2%)	48 (22.4%)	
71 +	95 (8.4%)	46 (21.5%)	
Mechanism of injury			
Car	421 (37.2%)	60 (28.0%)	0.039
Head-on collision	52 (12.4%)	15 (25.0%)	
Rollover	59 (14.0%)	12 (20.0%)	
Fixed obstacle (wall, tree...)	29 (6.9%)	4 (6.7%)	
Off-road vehicle	6 (1.4%)	2 (3.3%)	
Simple rear-end collision	19 (4.5%)	2 (3.3%)	
Other/Unknown	256 (60.8%)	25 (4.7%)	
Motorbike crash	285 (25.2%)	55 (25.7%)	
Fall	191 (16.9%)	46 (21.5%)	
Other	154 (80.6%)	30 (65.2%)	
Intentional (suicide attempt)	17 (8.9%)	11 (23.9%)	
Domestic (elderly)	20 (10.5%)	5 (10.9%)	
Bike collision	116 (10.2%)	19 (8.9%)	
Pedestrian hit by vehicle	81 (7.1%)	25 (11.7%)	
Other	39 (3.4%)	9 (4.2%)	

Univariate analysis among non-major trauma and major trauma patients

**Chi-square test (or Fisher's exact test) for categorical variables; Mann–Whitney *U* test for continuous variables

Even in the most advanced systems, these problems are far from being solved because the mechanisms of trauma which prompt TTA and transportation to a Trauma Centre could not protect from overtriage [6, 12, 13].

The difficult definition of overtriage [13–15] can overcome the effort towards a correct setting of the system, for this reason, we analysed overtriage in three different definitions. Despite our high suspicion of excessive overtriage, we found that according to ACS-COT definition our overtriage rate is not far from being acceptable, with a 44.6% which was considered correct before the last edition [12] which was released after our registry and field triage protocol was implemented. Our data give room for improvement and validation of a new field triage protocol aimed to lower overtriage, especially in the subgroup of patients transported to our trauma centre because of the mechanism of trauma, in which overtriage range from 83.2 to 47.6% according to different definitions. Undertriage, despite the initial concerns, is not a problem at present because it is well within the accepted range [12], even if we had some negative events. One could argue that aiming to lower overtriage could be at risk to increase undertriage so, again, a prospective observational validation of a new field triage protocol is needed in our Province, considering our conclusions.

Mechanisms of injury or dynamics represent the clear majority of patients brought to our hospital by the TT and around a half of them are discharged from the ED. In this study, we estimated the rate of under-overtriage of the existing field triage protocol considering the TTA for mechanisms of trauma (see Fig. 1); we investigated the association between dynamics TTA and major trauma (ISS > 15). This is the first report of our experience so far. Our population is significantly ageing and age over 55 years old in itself is a significant risk factor for severe trauma. A more comprehensive triage field protocol for older adults should be provided because of better care for the elderly results in a better outcome if older patients are centralised to trauma centres [13, 16–18]. Furthermore, many studies emphasised the need for different field triage protocols for older adults that, if treated at a higher-level of Trauma Centre with expertise in

Table 3 Effect of gender, age and mechanism of injury on the risk of major trauma estimated by univariate and multivariable logistic regression model

	Univariate model OR (CI 95%)	Multivariable model OR (CI 95%)
Gender		
F	1.00 (Rif.)	1.00 (Rif.)
M	1.37 (0.97–1.94)	1.61 (1.09–2.36)
Age distribution		
18–55	1.00 (Rif.)	1.00 (Rif.)
56–70	1.87 (1.29–2.71)	1.99 (1.35–2.94)
71 +	3.45 (2.31–5.15)	3.69 (2.37–5.76)
Mechanism of injury		
Unknown	1.00 (Ref.)	1.00 (Rif.)
Car		
Head-on collision	2.50 (1.27–4.92)	2.44 (1.22–4.87)
Off-road vehicle	2.89 (0.56–14.90)	1.79 (0.32–10.01)
Rollover	1.76 (0.86–3.61)	1.67 (0.80–3.47)
Fixed obstacle (wall, tree...)	1.20 (0.40–3.61)	1.33 (0.43–4.10)
Simple rear-end collision	0.91 (0.20–4.09)	0.92 (0.20–4.23)
Bike	1.42 (0.78–2.59)	1.11 (0.60–2.06)
Fall		
Intentional (suicide attempt)	5.61 (2.43–12.97)	7.40 (3.13–17.52)
Domestic(elderly)	2.17 (0.76–6.15)	1.04 (0.35–3.09)
Other	1.69 (1.00–2.87)	1.23 (0.71–2.13)
Motorbike	1.67 (1.06–2.65)	1.68 (1.05–2.68)
Pedestrian	2.68 (1.51–4.74)	1.98 (1.07–3.65)

treating older patients, can achieve a lower mortality, even after major complications [17, 19, 20]. An age of 70 years old has been regarded as a criterion in itself to guide EMS in transporting trauma patients to higher-level Trauma Centres, giving expectations to an annual increase of one additional admission per day [20]. In our registry, we have no data regarding the correspondence of EMS triage to the injuries identified by the Trauma Team, so a modification in the trauma registry is due to the event to consider a higher-level of centralisation for elderly patients [21].

The multivariable analysis also showed that among all the car crash mechanisms of trauma only head-on collisions are associated with the risk of major trauma while all other mechanisms were not significantly associated. Other mechanisms which significantly affected the risk of major trauma, both in univariate and by adjusting by gender and age, were motorbike crash and pedestrian's trauma. Among the three types of falls (domestic, intentional and other), only intentional falls were strongly associated with major trauma, and this reflects the high risk of most severe injuries following suicide attempts that represent a larger group than domestic falls.

This study has several limitations. It is a single-centre retrospective study, so it is prone to selection bias, lack of data, and to limits due to the predefined data set in the registry. Another limit is the absence of data regarding patients triaged and treated in other hospitals. Personal communications from the EMS control room account for a total centralisation rate of trauma patients around 90% to our hospital. So, 10% of patients are triaged and treated in other hospitals. Furthermore, we have no information on the post-discharge period, giving that all data regard the index hospital admission.

Conclusions

Significant association with major trauma was demonstrated in the multivariable analysis of different mechanisms of trauma in patients triaged to Papa Giovanni XXIII Hospital, Bergamo, Italy, only for dynamics. A revision of the field triage protocol with a prospective validation is needed to improve overtriage that is above the suggested limits. Undertriage is not a concern at present, despite the chance of increasing given the new field protocol. A correct balance of the two is pivotal in the performance of our trauma system.

Compliance with ethical standards

Conflict of interest Stefano Magnone, Arianna Ghirardi, Marco Ceresoli and Luca Ansaloni declare no conflicts of interest.

Ethical standards All procedures performed in studies involving human participants were by the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Formal consent This is a retrospective study without sensible data. Formal consent was waived.

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