Injury, Int. J. Care Injured 47 (2016) 1555–1561

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Tree-based algorithm for prehospital triage of polytrauma patients

Arnaud Follin [a,*], Sébastien Jacqmin [a], Vibol Chhor [a], Florence Bellenfant [a], Ségolène Robin [a], Alain Guinvarc'h [a], Frank Thomas [a], Thomas Loeb [a,d], Jean Mantz [a], Romain Pirracchio [a,b,c,e]

[a] Service d'Anesthésie-Réanimation, Hôpital Européen Georges Pompidou, Université Paris 5 Descartes, Sorbonne Paris Cite, Paris, France
[b] Department of Anesthesia and Perioperative Care, San Francisco General Hospital and Trauma Center, University of California San Francisco, San Francisco, USA
[c] Département de Biostatistique et Informatique Médicale, INSERM U1153, équipe ECSTRA, Hôpital Saint Louis, Université Paris Diderot, Sorbonne Paris Cite, Paris, France
[d] SAMU 92, Hôpital Raymond Poincare, Université de Versailles St Quentin, Garches, France
[e] Division of Biostatistics, School of Public Health, University of California Berkeley, Berkeley, USA

ARTICLE INFO

Article history:
Accepted 18 April 2016

Keywords:
Polytrauma
Trauma care
Triage
Decision tree
Recursive partitioning

ABSTRACT

Background: There is a need for better allocation of medical resources in polytrauma, by optimizing both the over and undertriage rates. The goal of this study is to provide a new working definition for polytrauma based on the prediction of the need for specialized trauma care.
Methods: This is a prospective, observational study, performed in a specialized trauma center in Paris. All consecutive patients admitted for a trauma at a major trauma center in Paris were included in the study. The primary outcome was the need for specialized trauma care as defined by the North American consensus. The explanatory variables included basic variables collected on scene. The modeling approach relied on recursive partitioning based decision trees. Its prediction performance was evaluated both internally and externally on a validation cohort, and compared to the MGAP (Mechanism, Glasgow coma scale, Age and Arterial pressure) score.
Measurements and main results: 1160 patients were included in the analysis over a 3-year period (2012–2014), out of which 41% needed specialized trauma care as defined by the recent US guidelines. The decision tree outperformed the MGAP and reached an area under the receiver operating characteristic curve of 0.82 [0.79–0.84]. This optimal decision rule was associated with a sensitivity of 0.94 [0.92–0.96], a specificity of 0.48 [0.44–0.52]. A conservative decision rule (refer to a trauma center all patient with a predicted probability $\geq$0.34) would result in an undertriage rate of 5.7% and an overtriage of 52.3% (respectively 7% and 64% in the validation cohort).
Conclusions: Our tree-based decision algorithm is a user-friendly and reliable alternative to the preexisting scores, which offers good performance to predict the need for specialized trauma care.

Introduction

Trauma is a major cause of premature death and disability worldwide [1]. Appropriate prehospital triage and admission to a relevant hospital unit are associated with a better outcome [2]. Specifically, in severely injured patients, the survival rate is significantly improved if the patient is admitted to a level I trauma center [2–4]. The less severe patients may be appropriately treated in less specialized but sometimes closer hospitals, thereby avoiding overburdening the level I center [5,6].

Undertriage is defined as a decision not to refer a patient to a trauma center when he/she would have needed it. Conversely, *overtriage* is defined as a non-medically justified referral to a trauma center. In this context, as well as in many others, there is a great need for appropriate resource allocation, which means to minimize both over and undertriages. This may be considered as a difficult endeavor, as these two quantities are inversely correlated. The American College of Surgeon [7] and the Center for Disease

* Corresponding author at: Service d'Anesthésie-Réanimation, Hôpital Européen Georges Pompidou, 75015 Paris, France. Tel.: +33 156092974/630679490; fax: +33 156092551.
E-mail addresses: arnaud.follin@gmail.com (A. Follin), jacqmin_s@yahoo.fr (S. Jacqmin), chhorv@gmail.com (V. Chhor), florence.bellenfant@aphp.fr (F. Bellenfant), segolene.robin@hotmail.fr (S. Robin), alain.guinvarch2015@gmail.com (A. Guinvarc'h), fthomas@live.fr (F. Thomas), tloeb@invivo.edu (T. Loeb), jean.mantz@aphp.fr (J. Mantz), romainpirracchio@yahoo.fr (R. Pirracchio).

http://dx.doi.org/10.1016/j.injury.2016.04.024
0020–1383/

Control [8] stated that undertriage should be of less than 5 percent, while overtriage should not exceed 25–35 percent. An appropriate and precise assessment of patient severity on scene is crucial to achieve these goals.

It is usually the responsibility of the Emergency Medical System (EMS) providers to first evaluate the patients and rapidly identify those who would benefit from a trauma center. This is a difficult task since there is currently no consensual criteria to identify polytrauma patients [9]. The term *polytrauma* generally refers to patients suffering from several injuries, at least one of them being life threatening. The most frequently used definition is based on the Injury Severity Score (ISS) [10]. A threshold of 15 is used in most of the studies to define polytrauma because an ISS above 15 is associated with an average mortality rate of at least 10% [11]. However, the ISS is based on anatomical findings, and therefore cannot be calculated before hospital admission. Several prognostic models based on various combinations of predictors have been developed to better triage the patients on scene, none of them being widely used in practice [12–16]. As highlighted by Rehn et al. [17] in a recent systematic review, the main reason is their lack of practicality. Moreover, all scores used survival as an outcome, while the actual need for specialized trauma care, as consensually defined by Lerner et al. [18], may be more appropriate. As a consequence, triage decisions are usually highly conservative, leading to very low rates of undertriage but very high rates of overtriage [19–21].

The aim of our study was to provide an easily implementable tree-based algorithm to improve early clinical decision-making and help to identify the patients who need specialized trauma care.

Material and methods

This study was based on an anonymized prospective trauma registry and did not alter the standards of care. All patients admitted at our institution are informed that some of their information may be used anonymously for observational research purposes.

Setting

The study was performed in a 800-bed specialized Trauma Center (Hôpital Européen Georges Pompidou) in Paris, France. In France, prehospital triage is performed by a physician-staffed prehospital EMS. After initial clinical evaluation and resuscitation, the physician on scene and a dispatching physician both determine the most adapted hospital the patient should be referred to. Triage is based on the recommendations from the French Society of Emergency Medicine (SFMU) [22]. The decision to refer a patient to a trauma center is essentially based on (1) his medical history (age >65, cardiac or pulmonary disease, pregnancy, coagulopathy), (2) initial vital parameters before giving any sedation or paralyzing agent (Glasgow coma Scale (GCS) <13), (3) systolic blood pressure (SBP) <90 mmHg, (4) pulse oxymetry (SpO_2) <90%), (5) identified lesions (any penetrating trauma, limb amputation or ischemia, severe burns or smoke intoxication, pelvis dislocation, flail chest, suspicion of spine injury), (6) the trauma mechanism (fall >6 m, blast, other victims severity, ejection from a vehicle, global evaluation of the kinetic) as well as on (7) the treatments provided on scene (fluids >1000 mL, catecholamine infusion, mechanical ventilation, G-suit). Presence of at least one of these criteria (2)–(7) is sufficient to refer the patient in a level I Trauma Center.

Patients

All consecutive trauma patients admitted to our center between January 1st, 2012 and December 31st, 2014 were included in the analysis. The patients who experienced cardiac arrest before hospital arrival were excluded from the analysis, as they were unlikely to present the outcome of interest due to mortality bias. The patients with missing data on first heart rate were also excluded from the analysis. Missing data on other vital signs (blood pressure or pulse oxymetry) were tolerated as they could be related to patient severity. The following data were prospectively collected: demographic information, injury mechanism, first vital parameters systematically collected on scene (HR, SBP, GCS, SpO_2 and capillary hemoglobin (Hb)) by EMS, presence of an head injury or an obvious limb injury such as open fracture or amputation, treatments provided during the first 24 h in hospital (blood transfusion, emergency surgery, arterial embolization, intracranial pressure monitoring), length of hospital stay, length of ICU stay (if applicable), first Simplified Acute Physiology Score (SAPS II) [23] and ISS scores [10], and hospital mortality.

All patients of the cohort were initially hosted in a dedicated trauma bay in our ICU. After initial evaluation, all stable patients who did not need continuous monitoring were transferred to the appropriate facility. Unstable patients or patients needing continuous monitoring stayed in ICU.

A second cohort was used for external validation. This sample consisted of 287 patients admitted for trauma in our center between January 1st, 2015 and August 1st, 2015.

Endpoints and outcome definition

The primary goal of the study was to build a prediction algorithm for the need for specialized trauma care. This outcome was adapted from the North American consensus-based criterion standard for trauma center need [18]. Hence, ten indicators were used to define retrospectively the need for a trauma center: evidence for a spinal cord injury, advanced airway management, thoracotomy and/or pericardiocentesis and/or emergency cesarean delivery for treatment of the initial injury, intracranial pressure monitoring, need for interventional radiology and/or vascular, neurologic, abdominal, thoracic, pelvic, spine or limb-conserving surgery, in-hospital death. The threshold to define significant transfusion was a need for >3 packed red blood cells, >2 packed red blood cells and >2 fresh frozen plasma or >2 packed red blood cells and platelets concentrates. The presence of any one of these criterions defines the need for specialized trauma care.

Statistical analysis

Continuous variables are reported as means and standard deviations (SD) or as medians and 25th–75th percentiles [interquartile range] as appropriate. Categorical variables are presented as counts and percentages (%). The rate of missing data was far below 5% for all variables but first hemoglobin.

The association between the need for specialized trauma care (dependent variable) and the potential predictors (age, gender, SBP, HR, SpO_2, GCS, Hb, trauma mechanism, need for vasopressor and/or mechanical ventilation, head injury, obvious limb injury such as open fracture or amputation) was initially estimated using a main term fixed-effect multivariable logistic regression. The strength of association was expressed as odds ratios (OR) together with their 95% confidence intervals [95% CI].

In addition, in order to provide a user-friendly clinical decision-making algorithm that would also account for potential complex interactions between variables, we used a non-parametric classification tree-based approach. Specifically, the association between the need for specialized trauma care and potential predictors was explored using unbiased conditional inference based recursive partitioning [24] (partykit package for R [25]). One input variable was used to determine the decision at each node of