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Utility and Efficacy of Trauma Scoring Systems in Multiple Trauma Children with Cranial Computed Tomography

Kraniyal Tomografi Çekilmiş Çoklu Travmalı Çocuklarda Travma Skorlama Sistemlerinin Kullanılabilirliği

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Abstract

Introduction: To assess the association between cranial computed tomography (CCT) findings and Glasgow Coma scale (GCS), and abbreviated injury scale (AIS) and to investigate the efficacy of GCS for determination of the indication of CT in pediatric polytrauma patients.

Methods: This retrospective study was performed using the data of patients who admitted to the emergency department between February 2017 and June 2018. The 120 pediatric patients due to polytrauma were reviewed for demographic, clinical and radiological information. The relationship between GCS, AIS, and the presence of findings consistent with polytrauma in CCT was evaluated.

Results: Patients with positive findings on computed tomography (CT) had significantly higher AIS (p<0.001) and AIS squared (p<0.001) compared to those of patients without positive CT findings for trauma. The GCS and AIS squared scores were found to be significantly associated with positive findings for trauma in CT scans.

Conclusion: Trauma score systems such as GCS and AIS were associated with the presence of trauma in CCT in pediatric patients.

Keywords: Multiple trauma, computed tomography, Glasgow Coma scale

Öz

Giriş: Bu çalışmada, çoklu travması bulunan çocuklarda, kranial bilgisayarlı tomografi bulguları ile Glasgow Koma Skalası (GCS) ve kısaltılmış yaralanma ölçeği (AIS) arasındaki ilişkinin değerlendirilmesi ve BT endikasyonun belirlenmesinde GCS'nin etkinliğinin araştırılması amaçlanmıştır.

Yöntemler: Bu geriye dönük çalışma, Şubat 2017-Haziran 2018 tarihleri arasında çocuk acil servise çoklu travma nedeni ile getirilen 120 çocuk hastanın verileri kullanılarak yapılmıştır. Bu kayıtların demografik, klinik ve radyolojik verileri incelendi. KBT'de çoklu travma ile uyumlu bulguların varlığı ile GCS, AIS arasındaki ilişki değerlendirildi.

Bulgular: Çoklu travmalı çocukların bilgisayarlı tomografilerinde (BT) pozitif bulgusu olanların, pozitif bulgusu olmayanlara göre AIS (p<0,001) ve AIS squared (p<0,001) skorları anlamlı olarak daha yüksekti. Kullanılan GCS skorlamalarının, BT'de pozitif bulgu bulunması ile önemli ölçüde ilişkili olduğu bulundu.

Sonuç: Çocuk çoklu travmalı hastalarda çekilen KBT'deki travma kanıtı ile GCS ve AIS gibi travma skorlama sistemleri arasında ilişki olduğu gösterildi.

Anahtar Kelimeler: Çoklu travma, bilgisayarlı tomografi, Glasgow Koma skalası

Introduction

Trauma constitutes the leading cause of death among children in developed countries.[1] In case of trauma, computed tomography (CT) can be necessary for the successful treatment of life-threatening injuries. Whole-body CT (WBCT) scanning is often used in trauma centers as a single-pass primary assessment for traumatic injuries. Even though the specific imaging protocol is variable in different institutions,

***We are terribly sorry to announce that Ali Öztürk passed away. We thank her for him contributions.**

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WBCT mostly involves CT of the head and cervical spine as well as CT of the chest, abdomen, and pelvis with or without contrast material.[1]

The word "polytrauma" is usually defined in terms of a high injury severity score (ISS) and is sometimes interchanged with terms like "severely injured" or "multiple trauma".[2] The internationally accepted criterion is based on ISS ≥16 on the statement of an ISS of 16 as being indicative of a mortality risk of more than 10%.[2]

Polytrauma occurs infrequently in pediatric population; however, it has a higher rate of mortality.[3] Imaging modalities have a critical role in the evaluation and management of patients with polytrauma. In adult patients with severe trauma, the utility of WBCT is supposed to improve the survival rates.[4] On the other hand, risks associated with ionizing radiation must be taken into account during making a decision for use of WBCT in pediatric polytrauma patients.[5-7] The use of WBCT in pediatric patients remains controversial. Pediatric patients with trauma have different trauma patterns than adult patients, with injuries in children commonly being less severe, and posttraumatic interventions and operations are less frequently needed in them. However, children often undergo WBCT following trauma, with clinicians applying adult trauma protocols in pediatric trauma care.[8-10] Garcia and Cunnigham[11] reported that the indication for WBCT can be reliably and effectively established with respect to a combination of findings derived from history, physical examination and vital signs.The use of cranial CT (CCT) scans in children has been increasing, in part due to increased awareness of sports-related trauma.[12] The CCT scans are mostly obtained in the evaluation of blunt head trauma in children. These scans may detect unexpected incidental findings. A small but important number of children evaluated with CT scans after blunt head trauma may have incidental findings. Physicians who order cranial CTs must be ready to interpret incidental findings, communicate with families, and ensure appropriate follow-up.[13]

The trauma scoring system is an important aspect of triage, to compare the different types of trauma care and their quality. Glasgow Coma scale (GCS) is an important predictor of in-hospital mortality, but there is still concern about the suitability of using anatomical-based scoring systems.[14]

Novel scoring systems based on age-specific physiological criteria have been developed and attempts to compare and validate different scoring systems in pediatric patients have yielded varying results.[15] However, an ideal tool for prediction in pediatric trauma could not be still identified. The performance of trauma score may vary on the different systems of care as well as a different mechanism of injury.

In this study, we aimed to assess the relationship between cranial CT findings AIS and GCS. We aimed to reveal the efficacy of GCS for the determination of the indication of CCT in pediatric polytrauma patients.

Materials and Methods

Study Design

Following the approval of the local institutional review board (2019/09-31), we conducted a retrospective review of our hospital records. We included all children 18 years or younger who were initially admitted to the pediatric emergency department of the hospital due to polytrauma including blunt head trauma and underwent cranial CT as a component of WBCT (cranial, cervical and thoraco-abdominal CT images) from February 2017 to June 2018 in this study. Written informed consent was obtained from the patients' parents or legal guardians for the anonymized information to be published in this article.

The calculation of the sample size was based on a power analysis. At a power of 80% using a significance level of $p<0.05$, the sample size required was 110 subjects.

Exclusion criteria were pre-hospital cardiopulmonary arrest; non-blunt traumas such as penetrating injuries, burns, or unknown trauma mechanisms; and patients with incomplete or inaccessible CT data. It is noteworthy that thoraco-abdominal CT scans could not be reached in this series. Revised pediatric trauma scores (RPTS) were calculated with respect to information recorded in our HIMS data set and nurse follow-up sheets. The injuries were classified according to the site of involvement such as head, neck, face, thorax, abdomen, and extremities and type of injuries like external, abrasion, contusion, and burns.

The abbreviated injury scale (AIS), was calculated based on the sum of every anatomical site. The AIS squared is the sum of squares of the AIS of each anatomical region.

The original version of AIS was a scale of mixed severity and outcome and different AIS codes could be assigned to similar injuries. To overcome this problem, the revised AIS was developed and information for survival and severity were separated.

The GCS was recorded twice: One at admission and the next after the imaging study. The trauma mechanism was classified with respect to Pediatric Emergency Care Applied Research Network (PECARN) study.[16] Accordingly, type 1 injury mechanisms were defined as ground-level falls or running into stationary objects with clinical symptoms or signs suggestive of traumatic brain injury. Type 3 injury mechanism was defined as a motor vehicle collision with patient ejection, death of another passenger, or rollover; a pedestrian or cyclist without helmet struck by a motorized vehicle; falls (at a height of >3 feet for children 2 years and >5 feet for children 2 years); or the head struck with a high impact object. All other injury mechanisms were defined as type 2 injury mechanism.[16]

Severe injury is defined as patients who received a critical degree of force due to trauma mechanism as described in PECARN study. Moderate trauma was defined as a fall from a level equivalent to the patient's height which exposes the patient to a substantial force. All traumas else than these definitions were considered mild.[16]

All patients underwent monitorization of vital signs such as oxygen saturation, pulse, and respiratory rates as well as systolic and diastolic blood pressures.

Computerized Tomography Imaging

Computerized tomography images were obtained using a Toshiba Aquilion Prime CT (160-channel) device. All images were obtained at the same tertiary care center and stored by our picture archive and communication system. The measurements were carried out by 2 radiologists with 6-year and 9-year experience and they were blinded to the data of each other.

Outcome Measures

We aimed to analyze a total of 148 pediatric polytrauma patients who were diagnosed with blunt head trauma. However, data for 23 patients were either missing, unavailable or their CT scans were performed in other centers. Five patients refused to consent. Therefore, these patients were excluded from this study.

The independent variables used in this study were age and sex. The dependent variables were CCT findings, GCS at admission and at control, respiratory rate, arterial oxygen saturation, systolic and diastolic blood pressures.

Statistical Analysis

The calculation of the sample size was based on a power analysis. At a power of 80% using a 95 significance level of $p<0.05$, the sample size required was 110 subjects. Our data were analyzed using Statistical Package for Social Sciences program version 15.0 (SPSS Inc., Chicago, IL, USA). Univariate comparisons were conducted using various statistical tests. The normality of the continuous variables was assessed with Kolmogorov-Smirnov tests. Mann-Whitney U tests were used for continuous variables. Categorical variables were analyzed with chi-square tests, with Fisher's Exact correction where required. Multivariate logistic regression analysis was performed to evaluate the independent predictors of involvement in multiple sites in CT and the odds ratio (OR) for each predictor was calculated after adjusting for the effects of the variables that showed an association with $p<0.1$ in univariate analysis. ROC curve analysis was used to predict whether or not the parameters can assess the number of

Table 1. Comparison of the characteristics of patients with and without findings consistent with trauma in cranial CT scans

	Traumatic involvement in cranial CT scans		
	No detected pathologies in CT scans (n=82)	Detected pathologies in CT scans (n=38)	p-value
Age (months)	67.5 (1-187)	99 (8-192)	0.106[a]
Sex			0.089
Female	30 (36.6)	8 (21.1)	
Male	52 (63.4)	30 (78.9)	
Mechanism of trauma			0.127
1	73 (89.0)	38 (100.0)	
2	6 (7.3)	0 (0.0)	
3	3 (3.7)	0 (0.0)	
Trauma severity	4 (1-6)	3.5 (1-7)	0.497[a]
Glasgow Coma scale (GCS)	15 (13-15)	15 (3-15)	0.064[a]
Oxygen saturation (SO_2)	99 (94-100)	99 (75-100)	0.577[a]
Respiratory rate (RR)	24 (20-50)	24 (9-35)	0.628[a]
Systolic blood pressure (SBP)	117 (81-160)	113.5 (59-157)	0.228[a]
Diastolic blood pressure (DBP)	75 (45-107)	71.5 (30-94)	0.505[a]
Abbreviated injury scale (AIS)	1 (0-3)	4 (2-14)	**<0.001[a]**
AIS squared	1 (0-9)	7 (2-51)	**<0.001[a]**

Data expressed as n (%) or median (min-max). Bold p-values indicate statistical significance at α=0.05. [a]Multivariate logistic regression adjusted for all other variables, Mechanisms of trauma were defined in accordance with the definitions of Nigrovic et al.[16]

involvement in the CT scan. The cut-off values were calculated by estimation of 2 standard deviations from the difference between mean values of 2 groups under the independence assumption.

Results

An overview of baseline descriptives for our patient population (n=120) has been demonstrated in Table 1. This series consisted of 38 females (31.67%) and 82 males (68.33%). Patients with and without CCT findings consistent with trauma were compared in terms of demographic and clinical data. The detected pathologies on CCT images after blunt head trauma were cerebral contusion (n=17), subdural hematoma (n=9), skull fracture (n=9), subarachnoid hemorrhage (n=7), cerebral hematoma (n=6), and extra-axial hematoma (n=2). Patients with detected pathologies on CT had significantly AIS (p<0.001) and AIS squared (p<0.001) compared to those of patients without CT findings for polytrauma. Diagnosis for polytrauma was based on an ISS ≥16.[2] There was no significant difference between the 2 groups with respect to age, sex, mechanism or severity of the trauma, GCS, oxygen saturation, respiratory rate, as well as systolic and diastolic blood pressures.

As shown in Table 2, multivariate analysis was conducted with a logistic regression model adjusted for age, sex, and all the variables which were found to have p<0.1 in the univariate analysis. The adjusted R-Squared of the regression model is 0.870, which means that 87.0% of the variance in the detected pathologies in CT can be explained by the independent variables.

One unit increase in GCS decreased the risk of involvement in multiple sites in CT by 75.4% [odds ratio (OR): 0.246; 95% confidence interval (CI): 0.062-0.979; p=0.046] (Table 3).

GCS (cut-off: 13.5) demonstrated an accuracy of 0.649 (95% CI: 0.413-0.885, p=0.160). Systolic blood pressure (cut-off: 109.5) yielded an accuracy of 0.814 (95% CI: 0.651-0.977, p=0.003), whereas diastolic blood pressure (cut-off: 67.5) indicated an accuracy of 0.820 (95% CI: 0.612-1.000, p=0.003). The oxygen saturation (cut-off value: 97.5) demonstrated an accuracy of 0.781 (95% CI: 0.563-0.998, p=0.008). Respiratory rate (cut-off: 19) revealed an accuracy of 0.610 (95% CI: 0.324-0.897, p=0.160). Figure 1 demonstrates the ROC curve for GCS.

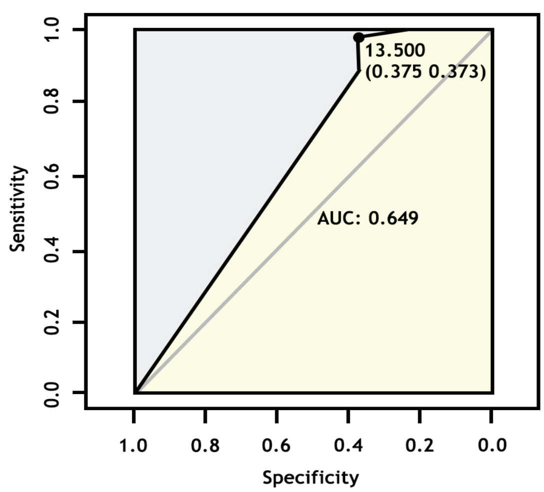

Figure 1. ROC curve for Glasgow Coma scale

Table 2. The results of multivariate analysis for variables associated with multiple traumatic involvement in cranial CT images

	OR	95% CI for OR	p[a]
Sex, male	2.792	(0.669, 11.652)	0.159
Age (months)	1.009	(0.998, 1.021)	0.109
GCS	0.246	(0.062, 0.979)	**0.046**

CI: Confidence interval, OR: Odds ratio. Bold p-values indicate statistical significance at α=0.05. [a]Multivariate logistic regression adjusted for all other variables, GCS: Glasgow Coma scale, CT: Computed tomography

Discussion

The aim of the present study was to seek whether various trauma scores were associated with WBCT findings in pediatric polytrauma patients. Our results yielded that the three trauma scores under investigation, the GCS was found to be significantly associated with involvement in multiple sites in CT. Systolic and diastolic blood pressures, as well as RPTS and oxygen saturation, provided useful hints for polytrauma in the

Table 3. ROC analysis for the relationship between presence of findings consistent with trauma in cranial CT scans and other variables

Variables	Optimum cut-off	AUC	95% CI	p[a]	Sensitivity (%)	Specificity (%)
GCS	13.0	0.649	0.413-0.885	0.160	97.3	37.5
RR	19.0	0.610	0.324-0.897	0.298	37.5	100.0
SBP	109.0	0.814	0.651-0.977	**0.003**	75.0	78.6
DBP	67.0	0.820	0.612-1.000	**0.003**	75.0	89.3
SO_2	97.0	0.781	0.563-0.998	**0.008**	62.5	90.2

AUC: Area under the curve, CI: Confidence interval, [a]Hyphotesis test for H0: AUC=0.5, GCS: Glasgow Coma scale, RR: Respiratory rate, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, SO_2: Oxygen saturation pediatric population. Our findings indicate that clues derived from GCS can be used to determine the need for WBCT in pediatric patients with polytrauma. Our data indicated that 82 children (68.3%) revealed no remarkable findings in CCT, while 38 patients (31.7%) had positive findings on CCT. A routine CCT cannot be routinely recommended for pediatric polytrauma patients; however, a CCT can provide useful data for the evaluation of trauma scores and the acquisition of predictive information in the pediatric emergency department. Previous publications have focused on rates of mortality rather than the relationship between trauma scores and the indication for CT.[17,18] Previous studies has shown that vital signs like heart rate, respiratory rate, and GCS may be more accurate predictors for in-hospital mortality [14]

Pediatric trauma patients presenting to referring facilities often undergo CT scans to identify injuries before transfer to a pediatric trauma center.[19] Attention must be paid for evaluation of CCT scans not to skip any cranial or central nervous system injury that may lead to significant morbidity and mortality. Emergency radiology has a critical role in the diagnostic process of a polytraumatized child. Radiological and ultrasonographic examinations play a critical role in hemodynamically unstable patients. In hemodynamically stable patients, CCT scanning may allow the examination of all the body parts of a polytraumatized child, thereby reducing the number of minor injuries which might otherwise be neglected.[20]

Recent publications did not support the view that the use of WBCT is associated with lower mortality than with the use of selective CT.[10] Considering the potential long-term risks of cumulative radiation exposure, they advocated the judicious use of CTs in pediatric patients with blunt trauma.[10] Our findings yielded that CCT may provide useful data for the triage and further management of pediatric patients with multiple trauma.

Even though trauma is the leading cause of death in the pediatric population in developed countries, trauma-related deaths are relatively rare. Thus, during the management of children with blunt trauma, clinicians should be careful about selecting the patients for CT. Pediatric polytrauma patients with less significant injuries may be considered as relatively unsuitable candidates for WBCT at initial admission. The indications for CT were not always based on simple vital signs or patient categories. Notably, hypotensive patients may be harmed due to CT procedure and patients with signs of shock must be resuscitated before WBCT scanning.[10] In terms of cost, no difference was reported between administration of selective CT and WBCT in trauma patients.[20] Decreasing the radiation exposure may provide long-term benefits in children, since non-life-threatening injuries can be alternatively detected during follow-up by selected regional CT or other non-radiation-associated modalities. The recognition and diagnosis of injuries, non-life-threatening injuries, or incidental findings during initial examination is still controversial. Thus, efforts must be spent to identify patients who require WBCT.

An important advantage of WBCT compared with the standard workup with radiographs, ultrasound, and selective CT scanning is the rapidity and completeness of evaluation for patients with life-threatening traumatic injuries. An important disadvantage of WBCT of patients with polytrauma is the increased exposure to radiation and incidental findings unrelated to trauma are more often found with WBCT than standard work-up.[21] Any delay during CCT can be due to time-consuming procedures such as patient transfer, and life-saving interventions in the trauma room.[21]

Although technological efforts still focus on diminishing the amount of radiation per CT scan, it is clear that any decrease in the number of unnecessary CT scans would be useful. To improve the cost-effectivity and safety of CT use in children with minor trauma, and to help clinicians with CT decision-making, clinical prediction rules were derived and validated by PECARN.[22]

Children with blunt head trauma and initial emergency department GCS scores of 14 or 15 and normal cranial CT scan results have a very low probability of later traumatic neuroimaging abnormalities and require very little neurosurgical intervention. Children with minimal head injuries should not be admitted to the hospital for neurologic surveillance if their CT scan results are normal.[23]

Children with minor head trauma and normal initial CCT scan results are at such a low risk of neurologic deterioration and neurosurgical procedures that hospitalization for serial neurologic tests is rarely required.[23,24]

Although some patients with minor blunt head injuries and normal cranial CT scan results may need to be admitted to the hospital for specific reasons, many of the individuals did not. Reduced hospitalization rates in this demographic have the potential to lower medical expenditures, alleviate hospital overcrowding, and provide better care to patients and their families.[23,24]

Hospitalized patients were more likely to have further imaging examinations (CT or MRI), and these subsequent imaging studies were more likely to reveal traumatic abnormalities. The convenience and accessibility of follow-up neuroimaging examinations in hospitalized patients is certainly one of the reasons. However, despite normal first CT scan results, emergency physicians were likely admitting patients with more severe head injuries who were more symptomatic.

The two critical questions remain to be answered in further trials: Who will benefit from initial total-body CT and what are the best screening criteria to identify those patients? In our opinion, answering these questions in trauma research will help us achieve the next level of evidence and improve patient safety in trauma care.

This study possesses certain limitations such as retrospective design, data restricted to the experience of a single-center and possible impacts of socio-economical factors. Moreover, working under the stressful conditions of the emergency department may affect the outcomes. The lack of CT findings of other sites such as thorax, abdomen, and pelvis constitutes another important restriction of the present study.

The blood pressure and respiratory rates may vary with the patients' age and lack of analysis of the performance of these vital signs corrected by the age is another restriction of our study. Further prospective, multi-centric trials on larger series are necessary to reach more accurate conclusions on the relationship between various trauma scores and the need for CCT in pediatric polytrauma patients.

Conclusion

To conclude, our results yielded that trauma score systems such as GCS, and AIS were associated well with the presence of polytrauma and therefore the need for CCT in the initial diagnostic study of pediatric patients admitted to the emergency departments. We suggest that ISS may have clinical implications in the emergency department settings since it had a predictive potential for the presence of polytrauma. In addition, hemodynamic and respiratory parameters such as pulse and respiratory rates, arterial oxygen saturation, systolic and diastolic blood pressures displayed association with the requirement for CCT. Even though our preliminary findings are promising, there is a need for further data to elucidate the relationship between trauma scores and the need for CCT in pediatric patients with polytrauma.

Ethics

Ethics Committee Approval: Following the approval of the local institutional review board of Dokuz Eylül University (2019/09-31).

Informed Consent: Retrospective study.

Peer-review: Internally and externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: Y.E.Ç., U.M., A.Ö., H.G.U., M.D., Concept: Y.E.Ç., U.M., A.Ö., H.G.U., M.D., B.B., Design: Y.E.Ç., U.M., A.Ö., H.G.U., M.D., B.B., Data Collection or Processing: Y.E.Ç., U.M., A.Ö., M.D., Analysis or Interpretation: Y.E.Ç., A.Ö., H.G.U., M.D., Literature Search: Y.E.Ç., A.Ö., H.G.U., M.D., Writing: Y.E.Ç.

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