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Predictive Value of Wisconsin Criteria in Trauma

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Abstract

Introduction:

Maxillofacial injury is seen in 20–25% of trauma patients and has an important role in trauma-induced morbidity and mortality. The aim of this study is to define the effectiveness of Wisconsin Criteria in our country to determine the need for computed tomography (CT) in maxillofacial traumas.

Methods

The data of 782 trauma patients who applied to our Emergency Departmant between July 2010 and July 2015, and who underwent maxillofacial and cranial CT, were retrospectively evaluated. Of these patients, 439 met the criteria and were included in the study.

Results

The median age of the patients was 37 years and 73.3% were male. The maxillofacial fracture was found in 62.6% (n = 275). There was a significant difference in terms of gender, loss of consciousness, limited gaze, and tenderness over the zygoma between patients with and without fracture as a result of CT imaging ($p < 0.05$ for each comparison). When evaluated for the Wisconsin Criteria for maxillofacial fractures; its sensitivity was 78.1%, its specificity was 70.7%, its PPV was 78.5%, and its NPV was 70.3%.

Conclusions

In our study, we examined clinical markers that would guide the determination of maxillofacial CT indications in maxillofacial trauma patients. We believe that the revision of Wisconsin Criteria's should be considered by addition of clinical findings such as loss of consciousness, limited gaze, and tenderness over the zygoma, which were found to be statistically significant in our study. Also, our study is a validation study of the Wisconsin Criteria for the Turkish population.

INTRODUCTION

Maxillofacial injury has an important role in trauma-induced morbidity and mortality (1, 2). Maxillofacial injury is seen in 20–25% of trauma patients (3, 4). They can be isolated or associated with cranial, cervical, or other serious injuries. These patients should be rapidly evaluated in emergency departments, and diagnostic imaging should be performed in patients with suspected maxillofacial trauma (5–7).

Due to the complex anatomy of the maxillofacial region, not only it is difficult to evaluate with plain X-rays but also they have low sensitivity. Maxillofacial Computed Tomography (CT) is the gold standard for

the diagnosis of maxillofacial fracture (8–10). The use of CT causes long-term side effects, increased cost, and workload due to radiation exposure (11).

There are no validated evidence-based guidelines for identifying who should undergo maxillofacial CT when evaluating patients with maxillofacial trauma. Therefore, unnecessary CT scans may be performed or pathologies may not be detected (12).

The Wisconsin Criteria (periorbital swelling or contusion, Glasgow Coma Scale (GCS) < 14, cascading or instability, malocclusion, and tooth loss), established in the study of Sitzman et al. seems useful (13). These five physical examination findings in the criteria; was determined based on retrospective studies that found a relationship between these findings and facial fractures. However, it is not clear whether the criteria are generalizable outside of Wisconsin (14). The aim of this study is to determine the effectiveness of the Wisconsin Criteria in our country to determine the need for CT in maxillofacial trauma and to evaluate the relationship between other clinical findings and maxillofacial CT results. In this respect, our study is a validation study of the Wisconsin Criteria for the Turkish population.

METHODS

This study was planned as a retrospective clinical study and was carried out in a university emergency department between 16/07/2010-15/07/2015 after obtaining the approval of the local ethics committee. All patients who were admitted to the emergency department with maxillofacial trauma and evaluated by CT were included in the study. Those who were referred from another center, patients under the age of 18, patients with missing database records, and penetrating injuries were not included in the study.

Patients' age, gender, blood alcohol level, GCS (15), AVPU (Alert-Verbal-Painless-Unresponsive) scale (16), intubation status on arrival, mechanism of injury, history of previous cranial-cervical operation or injury, loss of consciousness, whether or not using seat belt and helmet, physical examination findings and maxillofacial, cranial and cervical CT results were recorded in the study form.

In maxillofacial CT, sections were taken in the caudocranial direction from the inferior of orbita to the apex of the cranium for cranial CT and from the inferior of the mandible to the superior of frontal sinus for maxillofacial CT. The section thickness of serial axial images in tomography was 0.625 mm. Multiplanar; axial, sagittal, and coronal images were interpreted and reported by Gazi University Faculty of Medicine, Radiology Department faculty academic members.

During the five-year study period, the number of patients who applied to our emergency department due to trauma and underwent maxillofacial and cranial CT was 782. Of these patients, 439 met the criteria and were included in the study.

According to the Wisconsin criteria, if the patient does not meet any of the criteria, there is no need for imaging, while if he meets even one, he should be evaluated with maxillofacial CT. In our study, we

examined the Wisconsin criteria and other clinical findings to predict pathologies and if they can reduce unnecessary imaging.

Statistical Analysis:

Statistical analyses were performed using the SPSS software version 16. The variables were investigated using visual (histograms, probability plots) and analytical methods (Kolmogorov-Smirnov/Shapiro-Wilk's test) to determine whether or not they are normally distributed. Descriptive analyses were presented using means and standard deviations for normally distributed variables, medians, and range for the non-normally distributed and ordinal variables, frequencies for the categorical variables. In the comparisons between groups, the Student's t-test was used for normally distributed variables, the Mann-Whitney U test for non-normally distributed variables and ordinal variables, and the Chi-square or Fisher tests for categorical variables were used. A 2x2 table was used to calculate sensitivities, specificities, negative predictive values (NPV), and positive predictive values (PPV) of the Wisconsin criteria, and other clinical findings in the detection of facial fractures were calculated against maxillofacial CT as the gold standard. A p-value of less than 0.05 was considered to show a statistically significant result.

RESULTS

The median age of the patients included in the study was 37 years (range, 19–94), and 73.3% of the patients were male. Considering the mechanism of patient injury; while the most common ones were interpersonal violence with 31.7% and falling from a height with 29.8%, the least common were motorcycle and bicycle accidents (0.9%) (Table 1).

Table 1
Distribution of Descriptive and Clinical Characteristics of the Patients

Age (year)	**n (%)**
Mean±Standard Deviation	**43,21 ± 18,34**
Median (min-max)	37 (19–94)
Gender	
Male	322 (73,3)
Female	117 (26,7)
Injury Mechanism	
Beat	139 (31,7)
Falling from high	131 (29,8)
Motor vehicle accident	97 (22,1)
Pedestrian	34 (7, 7)
Workplace accident	17 (3, 9)
Sport accident	9 (2, 1)
Motorcycle accident	8 (1, 8)
Bicycle	4 (0,9)
Values are given in numbers and percentages n (%)	

The maxillofacial fracture was found in 62.6% of the patients (n = 275). The orbital fracture was the most common with 34.9% (n = 153) and maxillary sinus fracture with 30.1% (n = 132) among simple fractures. Considering the complex fractures; while 3.2% (n = 14) of the patients had nasofrontoethmoidal fractures and only 1 (0.2%) had Le Fort II fracture, no Le Forte I and III fractures were found. Isolated nasal bone and maxillary sinus fractures were detected in 224 (51%) patients, and these patients were excluded because they did not require maxillofacial CT in the treatment management. Subsequent evaluations were made on 224 patients with fractures requiring maxillofacial CT (Table 2).

Table 2
Distribution of Maxillofacial Fractures by Computed Tomography Results

Simple Fractures	**n (%)**
Orbital fracture	153 (34,9)
Maxillary sinus fracture	132 (30,1)
Nasal arch fracture	101 (23,0)
Zygomatic arch fracture	63 (14, 4)
Frontal sinus fracture	42 (9, 6)
Alveolar bone fracture	18 (4, 1)
Complex Fractures	
Nasofrontoethmoidal fracture	14 (3, 2)
Zygomaticomaxillary complex fracture	6 (1, 4)
Orbital roof and ring fracture	6 (1, 4)
Nasomaxillary junction fracture	4 (0,9)
Le Forte Fractures	
1	0
2	1 (0,2)
3	0
Mandible Fractures	41 (9, 3)
Others	21 (4, 8)
Fractures in CT	275 (62,6)
Fractures Requiring CT*	224 (51,0)

* Direct radiography is considered sufficient for the diagnosis of isolated nasal arch and maxillary sinus fractures and/or CT does not affect the treatment approach. Therefore, the number and percentage of patients after excluding these fractures are given.

Values are given in numbers and percentages n (%)

CT: Computed Tomography

Some descriptive and clinical features were evaluated according to the fracture detection status in maxillofacial CT. Among the patients included in the study, there was a significant difference in terms of gender ($p < 0.001$) and loss of consciousness ($p = 0.049$) between patients with and without fracture as a

result of CT imaging. The percentage of men and those with loss of consciousness among patients with fractures as a result of CT was significantly higher than those without fractures. On the other hand, age ($p = 0.946$), mechanism of injury ($p = 0.065$), presence of intubation at presentation ($p = 0.998$), alcohol status ($p = 0.488$), and blood alcohol levels ($p = 0.520$) of patients with and without fractures were similar, there was no statistically significant difference. The GCS < 14 patients were more frequently detected with fracture when compared with GCS ≥ 14 patients ($p = 0.012$).

When the examination findings were evaluated, fracture was more frequent in patients with a positive physical examination finding of bone cascading or instability ($p < 0.001$), malocclusion ($p = 0.001$), eye movement disorder ($p = 0.028$), zygomatic ($p = 0.007$), nasal ($p < 0.001$) and maxillary tenderness ($p = 0.040$), laceration in the nasal ($p = 0.015$), malar ($p = 0.001$) and perioral ($p = 0.004$) regions, presence of contusion in the periorbital or any region ($p < 0.001$). On the other hand, there was no statistically significant difference was found in patients with or without fracture in terms of hemorrhage ($p = 0.905$), hematoma ($p = 0.156$), tooth loss ($p = 0.242$), facial numbness ($p = 0.998$), diplopia ($p = 0.655$), open fracture (0.655), change in vision ($p = 0.162$), and epistaxis ($p = 0.302$) (Table 5).

Table 5
Distribution of Physical Examination Findings According to Any Fracture Detection in Computed Tomography

Physical Examination Findings (n = 439)	**Any Fracture in Computed Tomography**		**p value**
	Yes (n = 275)	**No (n = 164)**	
	n (%*)	**n (%*)**	
AVPU Score			0,061
Mean±Standard Deviation	1,14 ± 0,52	1,01 ± 0,08	
Median (min-max)	1 (1–4)	1 (1–2)	
GCS Score			0,082
Mean±Standard Deviation	14,53 ± 1,86	14,96 ± 0,27	
Median (min-max)	15 (3–15)	15 (12–15)	
GCS Group			**0,012**
< 14	14 (5, 1)	1 (0,6)	
≥ 14	261 (94,9)	163 (99,4)	
Any Tenderness in Physical Examination	*105 (38,2)*	*69 (42,1)*	*0,420*
Zygomatic	27 (9, 8)	31 (18, 9)	**0,007**
Nasal	50 (18, 2)	5 (3,0)	**< 0,001**
Maxillary	23 (8, 4)	24 (14, 6)	**0,040**
Mandibular	27 (9, 8)	18 (11,0)	0,699
Any Laceration in Physical Examination	*113 (41,1)*	*73 (44,5)*	*0,483*
Periorbital	49 (17, 8)	21 (12, 8)	0,165
Forehead	37 (13, 5)	14 (8, 5)	0,120
Scalp	20 (7, 3)	14 (8, 5)	0,632
Nasal	25 (9, 1)	5 (3,0)	**0,015**
Malar	9 (3, 3)	18 (11,0)	**0,001**
Perioral	7 (2, 5)	14 (8, 5)	**0,004**

*Column percentage; [a]Fisher's Final Test, Statistically significant *P*-values are written in bold

GCS: Glasgow Coma Scale

Physical Examination Findings (n = 439)	**Any Fracture in Computed Tomography**		**p value**
	Yes (n = 275)	**No (n = 164)**	
	n (%*)	**n (%*)**	
Mandible	10 (3, 6)	5 (3,0)	0,743
İntraoral	6 (2, 2)	6 (3, 7)	0,377[a]
Any Contusion in Physical Examination	*168 (61,1)*	*63 (38,4)*	**< 0,001**
Periorbital	148 (53,8)	39 (23,8)	**< 0,001**
Malar	20 (7, 3)	14 (8, 5)	0,632
Forehead	15 (5, 5)	8 (4, 9)	0,739
Nasal	11 (4,0)	2 (1, 2)	0,144[a]
Skalp	2 (0,7)	6 (3, 7)	0,057[a]
Mandibular	4 (1, 5)	1 (0,6)	0,655[a]
Zygomatic	1 (0,4)	0	0,998[a]
Bone cascading or instability	58 (21, 1)	4 (2, 4)	**< 0,001**
Subconjunctival hemorrhage	16 (5, 8)	10 (6, 1)	0,905
Malocclusion	23 (8, 4)	1 (0,6)	**0,001**
Tooth loss	15 (5, 5)	5 (3,0)	0,242
Hematoma	3 (1, 1)	5 (3,0)	0,156[a]
Eye movement disorder	8 (2, 9)	0	**0,028[a]**
Facial numbness	5 (1, 8)	2 (1, 2)	0,998[a]
Diplopia	4 (1, 5)	1 (0,6)	0,655[a]
Open fracture	4 (1, 5)	1 (0,6)	0,655[a]
Change in Vision	5 (1, 8)	0	0,162[a]
Epistaxis	4 (1, 5)	0	0,302[a]

*Column percentage; [a]Fisher's Final Test, Statistically significant *P*-values are written in bold

GCS: Glasgow Coma Scale

Physical Examination Findings (n = 439)	Any Fracture in Computed Tomography		p value
	Yes (n = 275)	No (n = 164)	
	n (%*)	n (%*)	
Face swelling	1 (0,4)	1 (0,6)	0,998[a]
Ear injury	1 (0,4)	0	0,998[a]
*Column percentage; [a]Fisher's Final Test, Statistically significant *P*-values are written in bold			
GCS: Glasgow Coma Scale			

When the sensitivities of the physical examination findings of the patients were evaluated, the ones with the highest sensitivities were any contusion and periorbital contusion with 64.3% and 57.6%, respectively. When the specificities of the physical examination findings were examined, the two most specific findings were malocclusion and GCS < 14 with a rate of 99.4%. When the PPV of the physical examination findings were examined, the highest ones were malocclusion, GCS < 14 and bone cascading and instability with 95.8%, 93.3%, 93.2%, respectively. Considering the NPV of the physical examination findings, the highest ones were periorbital contusion with 56.8% and any contusion with 55.8%. When evaluated for the Wisconsin Criteria for maxillofacial fractures; its sensitivity was 78.1%, its specificity was 70.7%, its PPV was 78.5%, and its NPV was 70.3% (Table 3).

Table 3
Sensitivity, Specificity, Positive and Negative Predictive Values of Some Physical Examination Findings for Facial Fractures

Physical Examination Finding	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Face Numbness	2,2	98,8	71,4	42,5
Any Laceration	43,3	55,5	57,1	41,7
Any Contusion	64,3	61,6	69,6	55,8
Cascading or instability	24,6	97,6	93,2	48,6
Malocclusion	10,3	99,4	95,8	44,8
Tooth Loss	6,3	97,0	73,7	43,1
Periorbital Contusion	57,6	76,2	76,8	56,8
GCS < 14	6,3	99,4	93,3	43,7
Wisconsin Criteria	78,1	70,7	78,5	70,3
* PPV: Positive Predictive Value; NPV: Negative Predictive Value GCS: Glasgow Coma Scale				

The rate of reduction of maxillofacial CT scans if they were taken according to the examination findings and the rate of failure to detect clinically important pathologies were examined. If maxillofacial CT had been taken according to the Wisconsin Criteria, the CT rate would have decreased by 29.9% (n = 116). On the other hand, if CT had been performed according to the Wisconsin Criteria, 12.6% (n = 49) of the maxillofacial fractures would not have been detected. In case of applying the Wisconsin Criteria, 34.7% (n = 17) of the patients whose fractures could not be detected were hospitalized and operated (Table 4).

Table 4
Reduction Rate of Physical Examination Findings in Computed Tomography and Distribution of Undetected Fractures

Physical Examination Findings	**CT Reduction Rate**	**Undetected Fractures**
(n = 388)	**n (%)**	**n (%)**
Face Numbness	162 (41,8)	219 (56,4)
Any Laceration	91 (23,4)	127 (32,7)
Any Contusion	101 (26,1)	80 (20, 6)
Cascading or instability	160 (41,2)	169 (43,6)
Malocclusion	163 (42,1)	201 (51,8)
Tooth Loss	159 (41,0)	210 (54,1)
Periorbital contusion	125 (32,2)	95 (24,5)
GKS < 14	163 (42,1)	210 (54,1)
Wisconsin Criteria	116 (29,9)	49 (12, 6)
GCS: Glasgow Coma Scale Values are given in numbers and percentages n (%)		

DISCUSSION

Maxillofacial injury has an important place in trauma-induced morbidity and mortality (1, 2). Maxillofacial injuries are seen in a significant proportion of trauma patients, and it is very important to evaluate these patients quickly and appropriately in the emergency department (13, 17). Diagnostic imaging is frequently used in emergency departments in patients with suspected maxillofacial trauma. Maxillofacial CT is considered as gold standard in the diagnosis of maxillofacial fractures (9). However, the issue of which patients should receive CT is still controversial, and there are no globally accepted algorithms on this subject. Therefore, clinical decision guidelines are needed to prevent unnecessary CT scans without missing clinically important pathologies in patients with maxillofacial trauma.

The Glasgow Coma Score is the most commonly used scoring system for monitoring the consciousness of trauma patients at the time of admission and afterward. The GCS guides the grading of traumatic brain injury and which patients should undergo brain CT. Sitzman et al. (13) conducted a study to establish a clinical decision marker for whom maxillofacial CT should be performed in maxillofacial trauma. According to the Wisconsin Criteria, they created in this study, it is stated that GCS can be used among decision markers for determining the indication of imaging in maxillofacial trauma patients. In our study, the role of GCS in determining the requirement of maxillofacial CT in maxillofacial trauma patients were examined, and statistically significant correlation was found between GCS < 14 and

maxillofacial fracture. One of the Wisconsin Criteria, GCS < 14, is a guide for maxillofacial CT in maxillofacial trauma, and the results of our study also support this.

Low GCS and loss of consciousness at presentation are important markers of maxillofacial injury in trauma patients. All these are also markers of severe trauma, and clinicians need to be careful and keep the examination threshold low in terms of cranial, cervical, and other injuries in addition to maxillofacial injury in these patients (18). Although there are some single-center studies (18) showing that loss of consciousness is an important clinical marker in showing maxillofacial fracture, to our humble knowledge there has been no multicenter randomized controlled studies. Similarly, in our study, the relationship between loss of consciousness and maxillofacial fracture was found to be statistically significant. Since the loss of consciousness and low GCS value reduce the reliability of examination findings, the imaging threshold should be kept low for maxillofacial injuries in these cases. In line with the results of this project, loss of consciousness at presentation might be a guide in maxillofacial CT in maxillofacial trauma patients.

In a prospective study conducted by Exadaktylos et al. (19) to establish a clinical decision-maker about who should undergo orbital CT in trauma patients, the sensitivity of periorbital swelling and contusion was 68.6%. In another study on this subject, it was reported that the most common examination finding in patients with maxillofacial fractures was periorbital ecchymosis (68.3%) (20). In a retrospective study on zygomaticomaxillary complex fractures which was included 468 patients, had been showed that 90.6% of zygomaticomaxillary complex fracture patients had periorbital ecchymosis (21). It is stated in these three studies that periorbital ecchymosis is a guide for maxillofacial CT in maxillofacial trauma. In our study, periorbital contusion was found in 53.8% of patients with maxillofacial fractures, and the sensitivity of this physical examination finding in detecting maxillofacial fracture is 57.6%. On the other hand, when all physical examination findings were examined, contusion sensitivity anywhere in the maxillofacial region was the examination finding with the highest sensitivity, and the presence of only periorbital contusion was found to be the second most sensitive physical examination finding in terms of showing maxillofacial fracture. The rate of patients with fractures in the absence of periorbital contusion was 24.5%. Examination findings with high sensitivity are preferred to create clinical decision marker and may be a guide for maxillofacial CT in maxillofacial trauma patients with periorbital contusion.

Among the physical examination findings, bone cascading or instability in the orbital bones is one of the most specific findings in terms of detecting orbital fractures, and studies have reported that the rate of not detecting orbital fractures is around 45% (19). Similar to the literature data in our study, the specificity of this finding was 97.6%, and the rate of failure to detect the injury was 43%. Among the other physical examination findings, malocclusion and tooth loss have a high specificity (99.4% and 97%, respectively), and the rate of not detecting orbital fracture is around 50%. When all maxillofacial bone fractures were examined, although there was a significant relationship between bone cascading or instability, malocclusion and maxillofacial fractures, no significant relationship was found with tooth loss. In the light of these data, bone cascading or instability and malocclusion may be a guide for maxillofacial CT for patients with maxillofacial trauma.

Sitzman et al (17) developed Wisconsin Criteria's in 2015 and reported the sensitivity and NPV of these Criteria's were 98.2% and 87.8% respectively. They stated that using the Wisconsin Criteria's could reduce the maxillofacial CT scan by 9.3% in patients presenting with maxillofacial trauma, and clinically significant pathology could not be detected in only 1.8% patients. None of the patients without pathology required surgical treatment. In our study, the sensitivity of the Wisconsin Criteria was 78.1%, while the NPV was found to be 70.3%. In case of using these Criteria's, the rate of maxillofacial CT withdrawal decreased by 29.9%, while the rate of failure to detect clinically important pathologies was found to be 12.6% (n = 49). Of 49 patients with clinically significant pathological findings that could not be detected according to the Wisconsin Criteria, 34% (n = 17) were treated surgically. Therefore, due to its' low sensitivity and the inability to detect clinically important pathologies in a significant number of patients (with a rate of 12.6%), using the Wisconsin Criteria's alone in determining the indication of maxillofacial CT in maxillofacial trauma patients would not be sufficient.

In conclusion, in this study, we examined clinical markers that would guide the determination of maxillofacial CT indications in maxillofacial trauma patients. The presence of loss of consciousness at the time of admission is an important guide for maxillofacial CT. GCS < 14, which is one of the Wisconsin Criteria, guides the maxillofacial CT scan for bone cascading or instability, malocclusion, and periorbital contusion. Tooth loss, which is one of the Wisconsin Criteria, was not found to be statistically associated with maxillofacial fracture, and it might be more appropriate to use other findings such as limited gaze or tenderness over the zygoma. Although all Wisconsin Criteria except tooth loss are guiding in maxillofacial CT, the use of Wisconsin Criteria alone does not seem appropriate not only due to its' low sensitivity but also its' inability to detect clinically important pathologies. The revision of Wisconsin Criteria's should be considered by addition of clinical findings such as loss of consciousness, limited gaze, and tenderness over the zygoma, which were found to be statistically significant in our study. In this way, the sensitivity of the Wisconsin Criteria can be increased and missing of clinically important pathologies can be avoided. The results of these studies should be validated with prospective and multicenter studies where the mentioned limitations can be eliminated and their usability as a clinical decision-maker should be evaluated.

The most important limitation of this study is that it is a retrospective study and therefore the accuracy of the examination findings cannot be evaluated clearly. As with all retrospective studies, the quality of findings and records might have been affected the results of the study. The exclusion of patients with missing records and penetrating trauma in our study might have caused inevitable selection bias. Another important limitation is that our study was conducted in a single center and the emergency department of a university hospital. Therefore, generalizing the results of the study to all maxillofacial trauma patients and/or other emergency services would not be appropriate.

Declarations

Author contributions

Dr U.G. and Dr M.A.K.designed and conceptualized the study. Dr U.G., Dr O.G., Dr S.U., Dr H.A.D. and Dr S.G. collected and analyzed the data. Dr H.K.K. interpreted the images of tomographies. Dr U.G. and Dr M.A.K. drafted and revised the manuscript for intellectual content. All the authors approved the article to be published. All the authors participated sufficiently in the work to take public responsibility for appropriate portions of the content. The authors alone are responsible for its contents and writing of the article.

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Availability of data and materials

The data underlying this article will be shared on reasonable request to the corresponding author.

Informed consent

Written informed consent was not required by research ethics committee as this is a retrospective study without patient intervention and no identifiable patient data have been included in the manuscript.

Ethical approval

The protocol of the study was approved by the Gazi University Ethics Committee with the number 79/23.11.2015. Our study was conducted in accordance with the 1964 Declaration of Helsinki and its later amendments.

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