Original Article

Wisconsin Criteria and Necessity for Computed Tomography in Patients with Maxillofacial Trauma: A Diagnostic Value Study

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Abstract

Background and Objectives: Wisconsin criteria have already been introduced to diagnosis maxillofacial fractures and reduce unnecessary computed tomography (CT) and as a result radiation exposure. Given that its use in different centers has had different results, this study tries to investigate the diagnostic value of these criteria in a Level III trauma center. **Methods:** Over the study period, all patients with facial trauma presenting to the hospital emergency evaluated for the study eligibility criteria. Maxillofacial CT in all patients was performed. A senior radiology resident who was blinded to the study reviewed the CT images. The diagnostic value of the Wisconsin criteria, including correct classification (CC), sensitivity (SEN) and specificity (SP), and positive and negative predictive values (NPV) was calculated. **Results:** A total of 300 patients most of whom were injured in traffic accidents (74%) met the inclusion criteria; most of whom were men (90.7%). The mean age of the patients was 33 years. The highest diagnostic value of the Wisconsin criteria is in identifying fractures in the frontal region with a CC of 80.2%. The SP and positive predictive value (PPV) of Wisconsin criteria at the cutoff point of 2 was 85.7% and 87.1%, respectively. SEN and NPV were obtained 23.9% and 21.8%, respectively. **Conclusions:** Regarding poor obtained SEN and NPV and the not so high SP and PPV of the test, our study could not validate Wisconsin criteria for predicting facial fractures. It seems that these criteria are institutionally dependent and cannot be generalized to all medical centers.

Keywords: Computed tomography, diagnostic value, fracture, maxillofacial, X-Ray

Introduction

Maxillofacial fractures are usually caused by high-energy accidents, especially traffic collisions and generally, 24% of trauma victims suffer from facial injuries.[1] These injuries, if mismanaged, can lead to permanent asymmetry, facial disfigurement, jaw injuries, and enophthalmos.[2-6]

At present, computed tomography (CT) is the imaging modality of choice when assessing a traumatic facial injury and can demonstrate a 100% sensitivity (SEN) in detecting a fracture.[7-12] However, proper physical examinations for early detection and triage of facial findings are crucial.

In the past, physical examination was the first step by which a physician evaluated a patient with facial trauma[13] and certain physical examination findings were related to the presence of zygomatic,[12,14-16] orbital,[8,12,13,16] maxillary,[12,14,16,17] mandibular[12,18-20] and nasal fractures.[12,21] However, these

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findings have not been systematically tested against CT scans to determine which findings are significantly more predictive of facial bone fractures in trauma patients.

The use of CT scans in the world has increased dramatically since 1980.[22,23] In many treatment centers, patients often undergo a CT scan before receiving a full physical examination by a physician.[20,24] The use of CT scans in patients who are less likely to have facial bone fractures due to trauma can lead to over-imaging, unwarranted radiation exposure and ultimately a marked increase in costs. In fact, about 30% of CT scans performed are unnecessary.[25] In addition, increased radiation exposure increases the risk of cancer, especially in children.[23,25-27]

Based on these facts about overusing of radiological imaging, several other studies have developed valid diagnostic tools to reduce unnecessary imaging. One such study was conducted in 1993 with the Ottawa Ankle Rules, which evaluated a number of clinical signs to assess ankle bone injuries.[28] These methods showed a positive predictive value (PPV) of 100% for fracture diagnosis, thereby reducing the use of X-ray radiography by one-third. Furthermore, by reducing the use of unnecessary imaging techniques, the treatment costs of exposure to unnecessary radiation were reduced.

According to a multi-center study conducted in 2009,[29] each CT scan of the head emits about 2 mSv per scan, which is ten times more than the amount of radiation received from a typical X-ray image. Not only CT delivers much higher radiation doses than do conventional diagnostic X-rays but also patients often have multiple CT scan on admission. A study by Mettler *et al*.[30] reported that one-third of patients who underwent abdominal and pelvic CT scans received more than 3 scans and about 4% received more than 9 scans and many of them had multiple scans on the same day.

In 2011, the "Wisconsin criteria" were established as a guide in determining which patients would benefit from facial CT scan.[31] This study demonstrated a SEN of 98.2% in diagnosing facial fracture if ≥one of the following five clinical findings were positive: (1) Bony step-off/instability, (2) periorbital swelling/contusion, (3) Glasgow Coma Scale (GCS) score <14, (4) malocclusion, and (5) tooth absence. The same authors had a follow-up study with internal validation showing 97.4% SEN.[32] Unfortunately, an attempt of external validation by Harrington *et al*.[33] showed 81% SEN and 60% negative predictive value (NPV), raising concerns for the widespread use of this criteria.

Since the diagnostic indicators such as SEN and specificity (SP) in this case are rather controversial, and there is no general agreement about their diagnostic value regarding facial fractures, the current study was designed to prospectively test the diagnostic value of the Wisconsin Criteria including correct classification (CC), SEN, SP, PPV, and NPV as compared to CT scan (as the gold standard) in patients with facial traumas.

Methods

Study design and inclusion criteria

The Kashan University of Medical Sciences (KAUMS) institutional review board approved this prospective diagnostic study before commencement (Ethical code: IR.KAUMS.MEDNT.REC.1396.38). Between February 2018 and January 2019, all patients with facial trauma who admitted to the Kashan Shahid Beheshti Hospital (affiliated to KAUMS) emergency department evaluated for study eligibility criteria. Patients were excluded if they had active facial infection, facial palsy, history of past facial plastic surgery, mental status changes that led them unable to answer to physician's questions or if they have been admitted ≥7 days following the initial trauma. Patients also who were unable to give informed consent for any reason, such as endotracheal intubation, were excluded from the study.

Physical examination form

In the emergency department, all patients who had facial trauma were examined by a single emergency medicine specialist and the Wisconsin criteria[31] were calculated based on their physical examination.

Wisconsin criteria

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Radiologic imaging

Maxillofacial CT in all patients was performed from the skull apex caudally to the mandible. Serial axial images were obtained at 2.5 mm slices. Coronal and sagittal reformations were routinely performed. A senior radiology resident who was blinded to the physical examination results reviewed the original CT images. All fractures of the mandibular, maxillary, nasal, orbital, zygomatic, and frontal bone areas were systematically classified based on the diagnostic schemes proposed in the literature.[34]

Statistical analysis

A previously published set of physical examination findings, known as the "Wisconsin criteria" was used to test how accurate this tool is in our own study population. Using the CT findings as the gold standard, major facial areas in the CT and "Wisconsin criteria" were compared. A review of all patients fulfilling the inclusion criteria was performed, which assessed the following five criteria: Bony step off, periorbital swelling, GCS score <14, dental malocclusion, and tooth absence. The percent agreement between these results and the true CT findings were subsequently calculated.

True positive (TP), true negative (TN), false positive (FP), and false negative (FN) values were calculated to determine

the diagnostic value indices such as CC, SEN, SP, NPV and PPV, and area under the curve (AUC) for these five criteria in detecting facial fractures along with 95% confidence intervals (CI) (95% CI).(CC= (TP + TN)/all cases, SEN = TP/TP + FN, SP = TN/TN + FP, PPV = TP/TP + FP and NPV = TN/TN + FN). Statistical significance was determined by a $P < 0.05$.

Results

During the study period, a total of 300 patients met the inclusion criteria; most of whom were men (90.7%). The mean age of the patients was 33 ± 16 years. The most common mechanism of injury was road traffic accidents (74%) [Table 1]. Regarding Wisconsin criteria, the diagnostic value of frontal fractures had the highest accuracy among other maxillofacial fractures with a CC of 80.1% [Table 2]. The SP and PPV of Wisconsin criteria at the cut-off point of 2 for whole face is 85.7% and 87.1%, respectively. In other words, cases with facial trauma who have a Wisconsin score of at least 2 are 87.1% more likely to have a fracture in at least one area of their face. On the other hand, people with no facial fracture had an 85.7% chance of having a Wisconsin criteria <2. The highest diagnostic value of the Wisconsin criteria is in identifying fractures in the frontal region. The 96.4% of cases with a Wisconsin score lower than 2, are less likely to have a frontal fracture. Furthermore, cases with a Wisconsin score of <1 do not have an 80.4%, 92.2%, and 88.2% chance of nasal, orbital, and zygomatic fractures, respectively. However, cases with an orbital fracture are 86.2% more likely to have a Wisconsin score of more than 1. The diagnostic value of Wisconsin criteria in diagnosing fractures of at least one area of the face is not very high (AUC = 0.55) and the highest diagnostic power is related to frontal fractures (AUC = 0.713), followed by maxillary (AUC = 0.68) and orbital fractures (0.679). The results of Table 3 show that the best cutoff point for a total facial fracture is 2 and for each of the facial components is 1 [Table 3].

Table 1: Demographic and injury variables of the study cases

Variable	Frequency, *n* (%)
Age (years), mean±SD	33±16
Gender	
Male	272 (90.7)
Female	28 (9.3)
Mechanism of injury	
Road traffic accident	222 (74)
Fall	30 (10)
Assault	27 (9)
Others	21 (7)

SD: Standard deviation

Table 2: Correct classification of Wisconsin criteria versus computed tomography scan regarding different maxillofacial fractures

Type of fracture	Fracture status (based on CT)	Wisconsin criteria		CC (%)
		Positive (%)	Negative (%)	
Whole face	Yes	54 (19.1)	172 (61)	36.2
	No	8 (2.8)	48 (17.5)	
Mandibular	Yes	54 (19.1)	46 (16.3)	39.1
	No	126 (44.7)	56 (19.9)	
Maxillary	Yes	36 (12.8)	54 (19.1)	71.6
	No	26 (9.2)	166 (58.9)	
Nasal	Yes	60 (21.3)	20 (7.1)	50.4
	No	120 (42.6)	82 (29.1)	
Orbital	Yes	50 (17.7)	8 (2.8)	51.1
	No	130 (46.1)	94 (33.3)	
Zygomatic	Yes	40 (14.2)	12 (4.3)	46.1
	No	140 (49.6)	90 (31.9)	
Frontal	Yes	14 (5)	8 (2.8)	80.1
	No	48 (17)	212 (75.2)	

CT: Computed tomography, CC: Correct classification

Discussion

This study set out with the aim of assessing the ability of Wisconsin criteria to diagnosing facial fractures. In general, this study showed regarding the PPV of 87.1%, the patients with a Wisconsin score of at least 2, are 87.1% more likely to have a fracture in at least one area of their face.

Although in the past the examination of trauma patients relied more on physical examination, in recent years, there has been an excessive reliance on CT scan to diagnose fractures in maxillofacial trauma patients. The use of CT scans for all patients burdens a high cost on both the patient and the national health system. Furthermore, improper use of CT scan leads to the patient receiving unnecessary radiation. Therefore, in an attempt to minimize unnecessary CT scan use, several other studies have attempted to demonstrate the predictive value of certain physical examination findings.

In the retrospective study by Sitzman *et al*.,[31] "Wisconsin" criteria were emerged as predictors for ordering facial CT imaging. In their study, they found the SEN and NPV of these criteria in the diagnosis of facial bone fractures 98.2% and 87.8%, respectively. Validation of these criteria by Sitzman *et al*.[32] and Stewart *et al*.[35] was consistent with the reference study (SEN = 97.4% and NPV = 81.3). However, recently there have been contradicting reports regarding the utility of these criteria in decision-making. A validation study by Harrington *et al*.[33] failed to do so on account of low SEN and NPV (SEN = 81% and NPV = 60%).

Understanding the differences in both study type and instrument purpose, we attempted to examine how the Wisconsin criteria would perform at our institution. Our demographic was similar to Sitzman's group regarding age, male predominance, and trauma mechanism. In the present study, different diagnostic value was obtained for different facial bones. For example, when applied retrospectively, the "Wisconsin criteria" were 86.2% and 76.9% sensitive in diagnosing of orbital and zygomatic fractures, respectively. The NPV for ruling out

Table 3: Diagnostic characteristics of Wisconsin criteria for the diagnosis of maxillofacial fractures

Wisconsin criteria	Cut off point	SEN (%)	SP (%)	PPV (%)	NPV (%)	AUC
Whole face	2	23.9	85.7	87.1	21.8	0.55
Facial bones fractured						
Mandibular	1	54	30.8	30	54.9	0.54
Maxillary	2	40	86.5	85.1	75.5	0.68
Nasal	1	75	40.6	33.3	80.4	0.594
Orbital	1	86.2	42	27.8	92.2	0.679
Zygomatic	1	76.9	39.1	22.2	88.2	0.591
Frontal	2	63.6	81.5	22.6	96.4	0.715

SEN: Sensitivity, SP: Specificity, PPV: Positive predictive value, NPV: Negative predictive value, AUC: Area under the curve

of orbital and zygomatic fractures was 92.2 and 88.2%, respectively. The present findings seem to be consistent to some extent with Sitzman *et al.* and Stewart's studies.[31,32,35] However, our study, despite its relatively high SP (85.7%) and PPV (87.1%), had SEN of 23.9% and NPV of 21.8% in diagnosing facial bone fractures as a whole. Nevertheless, having relatively high PPV, according to our results, it could be concluded cases with facial trauma who have a Wisconsin score of at least 2 are 87.1% more likely for having at least one facial bone fracture.

There are several possible explanations for the inconsistency of our results with previously mentioned studies. A possible explanation for this might be that, in Sitzman's study finding was considered positive if it was confirmed by any one of different practitioners examining the patients while in our study, examining the patients and filling the checklists was performed by a one physician. On the other hand, we know that when the SEN or NPV is high, it means that the FN is low. Another possible explanation for this discrepancy might be related to differences between devices in different centers. The use of older CT-scan devices may increase the number of FNs and affect diagnostic value tests. In reference studies for validating Wisconsin criteria, the CT scan images were reviewed by multiple board-certified radiologists, while in the present study, a senior radiology resident was responsible for interpreting the images. On the other hand, since the PPV depends on two factors, SEN and prevalence, due to the low SEN, the high prevalence of fractures can be considered as the reason for the higher PPV. Differences in the nature of the traumas in different areas can also be a reason for the discrepancy of the results too. For example, we had no penetrating trauma among of our cases.

Conclusion

Our study could to some extent validate Wisconsin criteria for predicting facial fractures. Our results showed that the best cutoff point for a total facial fracture is 2 and for each of the facial components is 1.

These criteria may be medical center specific and may not be generalizable to other centers. It is suggested that further multicenter studies be performed to determine criteria for diagnosing maxillofacial fractures and avoiding over-imaging to improve resource allocation.

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Conflicts of interest

There are no conflicts of interest.

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