Assessment of the Wisconsin Criteria at a Level I Trauma Center

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Abstract: The Wisconsin Criteria was developed for physicians evaluating facial trauma to determine the likelihood of facial fractures. Subsequent studies have not consistently validated these criteria. This study seeks to validate the Wisconsin Criteria and determine its utility in predicting operative facial fractures.

Retrospective chart review of the trauma database registry at a Level I Trauma Center was conducted from September 2011 to May 2019. Adult patients who had a complete facial examination by otolaryngology or plastic surgery as well as a head computed tomography scan completed, were included. Fisher exact test was utilized for statistical analysis ($P < 0.05$) and positive predictive value, and negative predictive value (NPV) were calculated with a 95% confidence interval.

After screening, 546 patients met eligibility, 448 had at least 1 finding of the Wisconsin Criteria, and 472 patients had facial fractures. The sensitivity of the Wisconsin Criteria for determining the presence of a facial fracture was 86.23%, the specificity was 44.59%, and the NPV was 33.67% ($P < .0001$). Malocclusion was the criterion most specific in determining if a facial fracture was present (98.65%), and Glasgow Coma Score < 14 was the least specific (67.57%).

The Wisconsin Criteria did aid in the identification of facial fractures in trauma patients with a comparable sensitivity, higher specificity, and much lower NPV than originally described. Further investigation should be done to validate the criteria in other large trauma centers.

Key Words: Facial fracture, facial trauma, sensitivity, specificity, Wisconsin criteria

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Trauma is a leading cause of morbidity and mortality in the United States (US) for patients under 65, which represents about 87% of the US population.[1,2] Craniomaxillofacial injury occurs in about one-fourth of all trauma patients and affects nearly 10 million Americans annually.[3,4] Trauma also has a significant financial impact that has been estimated at $400 billion per year which includes both lost wages and costs of care and management.[4] The leading causes of facial fractures in the US include assaults, falls, and motor vehicle accidents.[5] Motor vehicle accidents are a significant cause of midface fractures as well as facial lacerations; however, given increasing seatbelt use and automobile regulations, these fractures have decreased over time.[5,6]

Facial fractures are commonly seen at Level 1 Trauma Centers in the US and require a high degree of specific training to accurately diagnose and manage.[7,8] Physicians must decide in an acute setting whether a computed tomography (CT) maxillofacial scan is warranted to evaluate facial fracture. Unnecessary CT scans are not only costly but can subject the patient to additional radiation.

The Wisconsin Criteria was developed to assist in the identification of facial fractures in patients using five criteria: bony step-off or midface instability, periorbital swelling or ecchymosis, Glasgow Coma Scale (GCS) less than 14, malocclusion, or tooth absence.[9] Prior studies have evaluated the use of the Wisconsin Criteria and have found mixed results. Harrington et al[10] were unable to validate the Wisconsin Criteria with a sensitivity of 81% and a specificity of 41% in their study (n = 167). Stewart et al[11] evaluated and applied the Wisconsin Criteria to their trauma data bank and externally validated the criteria with a 95% sensitivity and 40% specificity of accurately identifying operative facial fractures (n = 840).

While the gold standard of diagnosing a facial fracture is CT, the Wisconsin Criteria can function as an expeditious clinical prediction tool.[12,13] Application of this criteria can assist in reducing the number of low-yield CT scans in patients with a lower probability of facial fracture. Stewart et al[11] determined retrospectively that had the Wisconsin Fracture criteria been used in lieu of CT, hospital savings would have amounted to $300,000 annually. Taken together, these findings warrant further investigation into the external validity of the Wisconsin Criteria. The aim of this present study serves to validate the Wisconsin Criteria in a large patient population at a Level 1 Trauma Center and determine its utility in predicting operative intervention.

MATERIALS AND METHODS

A retrospective chart review of trauma activations involving any facial trauma at Albany Medical Center's Emergency Department, a Level 1 Trauma Center, was conducted from January 2009 until May 2019. Study approval was obtained by the Institutional Review Board at Albany Medical College with a waiver of informed consent. Using Sorian Clinicals (Cerner, Malvern), patient charts, both electronic and transcribed records, were analyzed for relevant emergency department notes and consultations. Patients were excluded if records were incomplete, no formal face consult from the department of otolaryngology (ENT) or plastic and reconstructive surgery were obtained, or if patients did not have a CT head or CT maxillofacial scan. Reviewers (TK, PU, CH, MG, and AH) extracted data on the presence or absence of the Wisconsin Criteria from each patient chart (bony step-off or midface instability, periorbital swelling or ecchymosis, GCS less than 14, malocclusion, or tooth absence) and were blinded to the CT results. CT imaging was subsequently reviewed for the presence of facial fractures, and these were classified as operative facial fractures based on a previously defined framework.[14]

A two-sided Fisher exact test was utilized for statistical analysis. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and likelihood ratios were calculated with a 95% confidence interval to determine the predictive value of the Wisconsin criteria. Microsoft Excel (Microsoft, Redmond, WA) and Prism's Graph Pad (Prism, San Diego, CA) were used for data analysis.

RESULTS

This study initially identified 1123 patients with facial trauma in the trauma registry, and 546 patients met inclusion criteria (Fig. 1). Of these patients, 448 patients had at least 1 finding of the Wisconsin Criteria, and 98 patients did not meet the Wisconsin Criteria. There were 407 patients that had a facial fracture and 41 did not have a facial fracture. Of the 98 patients who did not meet the Wisconsin Criteria, 65 had a facial fracture and 33 did not have a facial fracture. The sensitivity of the Wisconsin Criteria for determining the presence of a facial fracture was 86.23%, the specificity was 44.59%, the PPV was 90.85%, and the NPV was 33.67% ($P < 0.0001$, Supplementary Digital Content, Table 1, http://links.lww.com/SCS/D928).

When evaluating patients who had a facial fracture, 205 patients had operative facial fractures, and 267 had nonoperative facial fractures (Supplementary Digital Content, Table 2, http://links.lww.com/SCS/D929). Of the 205 patients who had an operative facial fracture, 186 patients met the Wisconsin Criteria, and 19 patients did not. In the group of 267 patients with nonoperative facial fractures, 221 patients met the Wisconsin Criteria, and 46 patients did not. The sensitivity of the Wisconsin Criteria for determining the presence of an operative facial fracture was 90.73%, the specificity was 17.23%, the PPV was 45.70%, and the NPV was 70.77% ($P = 0.015$, Supplementary Digital Content, Table 2, http://links.lww.com/SCS/D929).

In this study population (N = 546), 82.05% of patients met the Wisconsin Criteria and had a facial fracture (Supplementary Digital Content, Table 3, http://links.lww.com/SCS/D930). When looking at the prevalence of each element of the Wisconsin Criteria, periorbital ecchymosis (61.36%) and a GCS < 14 (40.29%) were the most prevalent physical exam findings, followed by bony step-off (19.96%), missing tooth (15.02%), and malocclusion (7.69%). The individual criterion that predicted the presence of a facial fracture from most to least specific was malocclusion (98.65%), bony step-off (95.95%), missing tooth (89.19%), followed by periorbital ecchymosis (74.32%), and GCS score < 14 (67.57%). The PPV values for each criterion were the following: 97.62% for malocclusion, 97.25% for bony step-off, 94.33% for periorbital swelling or ecchymosis, 90.24% for tooth absence, and 89.09% for GCS < 14. Likelihood ratios for individual criterion were the following: malocclusion (6.43%), bony step-off (5.54%), periorbital swelling (2.61%), tooth absence (1.45%), and GCS < 14 (1.28%) (Supplementary Digital Content, Table 3, http://links.lww.com/SCS/D930).

Utilizing the receiver operating characteristics curve as a predictive modeling tool of the Wisconsin Fracture Criteria, this study found an area under the curve of 0.74 ($P < 0.0001$, Fig. 2).

There were 65 patients who had facial fractures but did not meet the Wisconsin Criteria. These fracture types were analyzed

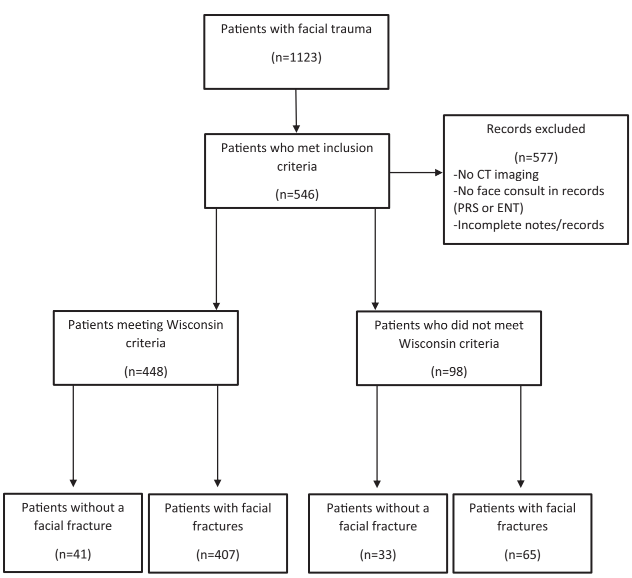
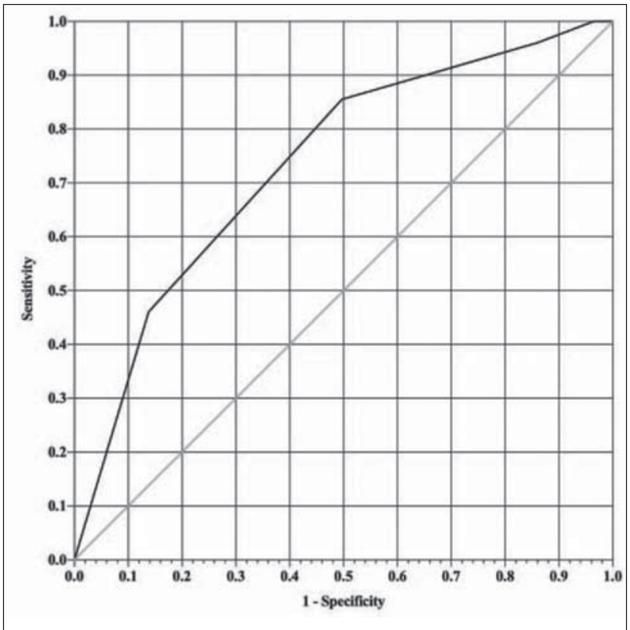


FIGURE 1. Flow diagram for selection process of determining study inclusion from Albany Medical Center trauma registry.



Area Under the Curve	0.7356
Standard Error	0.0303
95% confidence interval	0.6762 to 0.7950
P value	<0.0001

FIGURE 2. Predictive modeling of facial fractures using Receiver Operating Curve (ROC)-based on the Wisconsin Criteria.

and stratified by fracture type (Supplementary Digital Content, Table 4, http://links.lww.com/SCS/D931). Based on predetermined criteria, these fractures were classified as operative or nonoperative.[14] Many patients had multiple fracture types. Nasal fractures were most prevalent in the group overall (n = 23), and naso-orbito-ethmoid fractures were the least common (n = 2). Most maxillary fractures that did not meet the Wisconsin Criteria were nonoperative (n = 14). Likewise, most fracture types that did not meet the Wisconsin Criteria were more likely to be classified as nonoperative fracture. A notable exception was operative mandible fractures (n = 8), which were more prevalent than nonoperative mandible fractures (n = 3) in the group that did not meet the Wisconsin Criteria.

Both the sensitivity (86.23%) and specificity (44.59%) of the Wisconsin Criteria for predicting the presence of a facial fracture in this present study align with previous findings in the literature from the past decade (Supplementary Digital Content, Table 5, http://links.lww.com/SCS/D932).

DISCUSSION

The goal of this study was to externally validate the Wisconsin Criteria as a decision tool in predicting facial fractures given the conflicting research and data that is currently available. To date, this is the second largest study population in which these criteria have been validated (Supplementary Digital Content, Table 4, http://links.lww.com/SCS/D931). In this present study, the Wisconsin Fracture Criteria was externally validated at a Level 1 Trauma Center and demonstrated a sensitivity of 86.2% for all facial fractures and a sensitivity of 90.7% for operative facial fracture, making it a useful clinical prediction tool (Supplementary Digital Content, Tables 1, http://links.lww.com/SCS/D928 and 2, http://links.lww.com/SCS/D929). Moreover, the area under the curve of the receiver operating characteristics curve demonstrates that the Wisconsin Criteria can function as a fair diagnostic test for the presence of a facial fracture (Fig. 2).[11,15,16] Based on the sensitivity and PPV found in this study, the Wisconsin Fracture Criteria can function as a valuable clinical screening tool in facial fractures and operative facial fractures at institutions around the country.[17,18]

When evaluating the individual criterion, the specificities of bony step-off, GCS < 14, malocclusion, and tooth absence were similar to the findings by Sitzman et al in their internal validation study (Supplementary Digital Content, Table 3, http://links.lww.com/SCS/D930).[19] In this study, the finding of periorbital ecchymosis was the most prevalent at 61.3%, which is in line with the validation study by Stewart et al.[11] The physical exam findings of malocclusion and bony step-off demonstrated the greatest specificity, positive predictive value, and likelihood ratio, which aligns with the specificities found in prior research.[10,19,20] Interestingly, malocclusion was the least prevalent documented physical exam finding at 7.7%, yet demonstrated the highest specificity, PPV, and facial fracture likelihood ratio. Given the mobility of the mandible, its parabolic shape, and unique force distribution properties, the lower face is not only predisposed to fractures but occlusal derangements as well.[21–25] These findings and properties make malocclusion evaluation an important physical exam finding in facial trauma patients.

GCS is a widely used 15-point score for classifying the severity of traumatic brain injuries. The scale denotes a score of 3 to 8 as severe, 9 to 13 as moderate, and14 to 15 as mild traumatic brain injury . Multiple etiologies can account for a low GCS score, including head trauma, hemorrhage, strokes, substance abuse, and other neurovascular processes.[2] Therefore, a GCS < 14 is very prevalent in a trauma and non-trauma population and therefore, not as specific as other indicators. In fact, GCS had the lowest specificity and the lowest likelihood ratio of all the Wisconsin criteria. This parallels the finding of Harrington et al. that a GCS < 14 had the second lowest specificity and the lowest PPV of all 5 criteria.[10] It is possible that physicians are more comfortable using this criterion, especially since this is a component of any trauma evaluation, and providers are therefore more likely to assign a GCS < 14 to a patient in comparison to other components of the Wisconsin Criteria contributing to its low specificity.

While CT imaging is considered the gold standard for the evaluation of facial fractures, there are several caveats to its use. Exposure to ionizing radiation from a CT scan can predispose patients to the development of cancer and other malignancy, particularly in radiation-sensitive tissues, such as the skin, cornea, and thyroid gland.[10,13,27–29] In addition to these radiation risks, certain facial fractures are managed nonoperatively and may not benefit from additional CT imaging. For example, isolated nasal fractures that cause minimal airway compromise and no visible deformity may be conservatively treated.[30] Additionally, zygoma fractures with minimal midface deformation may also be nonsurgically treated provided there is no compromise to underlying orbital structures.[31] Moreover, the low and unfavorable reimbursement rate for CT imaging can contribute to the increasing financial burden that trauma centers face.[32] These factors collectively make the usage of the Wisconsin Criteria advantageous in clinical practice in screening for facial fractures.

When examining the subset of patients that did have facial fractures but did not meet the Wisconsin Criteria, 65 patients were identified with a total of 96 facial fractures (Supplementary Digital Content, Table 4, http://links.lww.com/SCS/D931). Naso-orbito-ethmoid fractures were uncommon (n = 2), and nasal bone fractures were the most common fracture type noted (n = 23) in this group. Since nasal bone fractures are often missed by providers or able to be managed nonoperatively, it is feasible that this common fracture pattern did not have any physical exam findings of the Wisconsin criteria, or the exam findings were subtle or incompletely documented. Often, the exam only yields a mild swelling of the nasal dorsum in a nondisplaced nasal bone fracture, and therefore, the Wisconsin Criteria would not apply. Fortunately, nasal bone fractures were managed nonoperatively in 78% of the patients in this group. One way to possibly increase the sensitivity of the Wisconsin Criteria would be to document any significant facial swelling not associated with a laceration as one of the criteria rather than just periorbital edema and ecchymosis, although this could have a detrimental effect and produce a high rate of false positives.

Over half of the fractures in this cohort were midface fractures. These fractures have a high rate of complications regardless of operative or nonoperative management, and surgery often can portend higher morbidity.[33–35] Orbital fractures pose a risk to the globe, including enophthalmos, entrapment, decreased visual acuity, whereas zygoma or maxillary fractures can cause similar visual issues, asymmetry, malunion, and a host of other complications if not treated. Even when treated, the same complications may occur in addition to malposition, sensory disturbances, infection, or hardware issues. Given the comparable risks, CT does serve to help guide treatment based on fracture pattern, and the Wisconsin Criteria, while useful in this scenario, does not predict these complications of midface fractures or operative treatment protocols. This study was limited in that it was not able to examine long-term complications in this patient cohort.

A majority of the fractures that did not meet the Wisconsin criteria were classified as nonoperative (77%) for all fracture types with a notable exception of mandible fractures. There were 11 mandible fractures in the cohort that did not meet the Wisconsin Criteria, and 8 of these were operative fractures (73%). The reason for this may be multifold. Possibly, there was incomplete documentation of physical exam findings by providers. Tooth absence and malocclusion are two of the Wisconsin Criteria that are often associated with mandible fractures. Although the Wisconsin Criteria can function as a valuable clinical prediction tool, these findings may warrant additional focus and attention. When evaluating tooth absence, this specific physical exam finding may be dismissed, especially in the context of a trauma patient who is comatose and hemodynamically unstable. Moreover, the physical exam finding of tooth loss may be difficult to extract in the context of patients who are edentulous and have poor baseline dentition.[23,36,37] Malocclusion is another example of a particular oral exam finding that is specific to facial subspecialties like otolaryngology, plastic and reconstructive surgery, and oral and maxillofacial surgery.[10] Similar to dental derangements, the precise alignment of the upper maxillary arch and the lower mandibular arch of teeth may be difficult to evaluate in patients who are either comatose, intubated, or have undergone maxillomandibular fixation.[38,39] This struggle in evaluating occlusion may account for the low sensitivity of malocclusion found in this study, the lowest of all five criteria, and similarly low sensitivity of 8.1% found by Harrington et al.[10]

One of the limitations of this current study is that this was a retrospective review conducted at a single center. Not all parameters of the Wisconsin Criteria were defined in advance and specifically evaluated by the provider at the time of patient evaluation. Selection bias may have impacted our findings given that patients without consultations by ENT and plastic and reconstructive surgery were excluded from this study. However, some focus was necessary given the wide variability in provider documentation among the various departments at our institution.

Another limitation of this study was that providers may have adjusted their approach to a focused physical examination based on the impression of the CT scan or the results of the patient's hospital course, treatment, and prognosis. These patients often present after a major trauma, intubated or obtunded with GCS much lower than 14. This compromises the utility of the criteria, and patients in this subset are imaged according to trauma protocol with a CT head and cervical spine regardless of physical exam findings of the Wisconsin Criteria. If such a patient is noted to have facial trauma, then they may undergo scanning before any face-specific specialty evaluation. Furthermore, craniomaxillofacial trauma patients are at high risk for other concomitant injuries, notably cervical spine trauma with an incidence of 4% to 10% and head injury incidence ranging from 28% to 80%.[40–43] The incidences increase when 2 or more separate facial fractures were identified. Low GCS and the need to rule out head and cervical spine injury may contribute to a higher probability of patients undergoing a CT maxillofacial scan, which lessens the utility of the Wisconsin criteria.

Future directions should evaluate the Wisconsin Criteria across multiple centers and include patients from a wider catchment area.[44] Additionally, future research should evaluate if the Wisconsin Criteria applies to specific populations, such as pediatric and elderly facial trauma patients.[45,46] There is also little data to gauge whether implementation of the Wisconsin Criteria enhances postoperative management outcomes or quality of life measures in patients. Cost is also a consideration, and analysis of hospital-related cost savings following implementation of the Wisconsin Criteria may be warranted. Specific training on assessing patients for the Wisconsin Criteria should be provided to doctors taking care of trauma patients, especially emergency medicine physicians and trauma surgeons who are often the first to evaluate these patients. While the instinct to jump to the CT scan for facial trauma evaluation may persist, especially in underserved communities and facilities that are not level 1 trauma centers, recent studies have sought to address this issue by developing interfacility transfer guidelines to help providers manage and triage the complex facial fracture patient and defray unnecessary costs.[47] This may even be beneficial to oral maxillofacial surgeons and otolaryngology providers that also frequently manage facial trauma but may not be as familiar with the Wisconsin Criteria. Given the importance of missing teeth and malocclusion, particularly in mandibular fractures, additional emphasis should be placed on recognizing significant oral exam findings to better assess facial trauma.[48]

The Wisconsin Criteria is a fair diagnostic tool for predicting the presence of facial fractures with a sensitivity of 86.2% and specificity of 44.6%, and most fractures that did not meet the Wisconsin Criteria were nonoperative. Periorbital ecchymosis was the most prevalent and sensitive physical exam finding for predicting facial fractures, and malocclusion was the most specific of the criteria. This is the second largest cohort analyzed and is comparable to previously published validation of the Wisconsin Criteria. Facial trauma patients should continue to receive the best standard of care and in cases of clinical ambiguity, should be managed by the closest Level 1 Trauma Center.[49,50]

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