A predictive model to identify women with injuries related to intimate partner violence

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Diagnosis of injuries related to intimate partner violence (IPV) is difficult. While interventions may prevent future IPV-related injuries, preventive actions cannot be initiated until the diagnosis is made. The diagnosis of IPV is challenging, because the condition has no obvious clinical characteristics, and there often is a mismatch of injury and diagnosis.[1-5] The clinical standard for identifying IPV-related injury and other injuries of nonverifiable etiology is the subject's self-report.[1-5] Other studies have suggested criteria for identifying victims of IPV seen in the emergency department (ED) and outpatient clinical setting.[6-13]

During the last decade, we and other investigators have been developing markers that may be applied in a variety of hospital settings to identify women with IPV-related injuries.[13-17] We identified two variables associated with IPV-related injuries. The first was injury location: head, neck or face (HNF) or other. The second was the subject's response to a standard IPV screening questionnaire, the Partner Violence Screen (PVS).[15-17] Preliminary studies suggest that clinicians can use injury location in conjunction with the PVS score to stratify (that is, as high or low) the risk of self-report of IPV-related injuries.[15-19] Other investigators have identified age, race, income,

ABSTRACT

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Purpose. The diagnosis of intimate partner violence (IPV) is challenging. The authors conducted a cross-sectional study to develop a predictive model to identify IPV-related injuries and validate the model with an independent sample.

Materials and Methods. The authors enrolled women older than 18 years seeking treatment for injuries. They randomized the sample into index and validation datasets. They used the index dataset to develop a predictive model; the validation set served as an independent sample for assessing the predictive model's goodness of fit. Study variables included risk of self-report of an IPV-related injury and demographic and socioeconomic variables. The outcome variable was self-reported injury etiology (IPV or other). The authors used multiple logistic regression techniques to develop a predictive model that they then applied to the validation dataset, and they measured goodness of fit with the Hosmer-Lemeshow test.

Results. The sample was randomized into index (n = 201) and validation (n = 104) sets. For the index set, age, race and risk of IPV were associated with IPV-related injuries ($P < .01$). The accuracy of the model was 92 percent. Application of the model to the validation dataset resulted in excellent agreement between the observed and actual number of women with IPV-related injuries (accuracy: 93 percent). No statistically significant differences existed between the observed and predicted outcomes ($P = .64$).

Conclusions. A predictive model composed of age, race and risk of experiencing IPV accurately characterizes women likely to report IPV-related injuries.

Clinical Implications. Once the clinician diagnoses IPV-related injury, he or she can intervene to prevent future IPV-related injuries.

Key Words. Intimate partner violence; maxillofacial trauma; diagnostic protocol.

JADA 2006;137:604-9.

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education and social history as risk factors for IPV-related injuries.[4,5,20-24]

We conducted a study to develop and validate a predictive model to identify women likely to report IPV-related injuries. We hypothesized that we could use injury location and responses to a screening questionnaire to stratify risk of self-report of IPV-related injuries and that the risk could be modified by other variables, such as age, race or marital status. The specific aims of the study were to develop a parsimonious, predictive multivariate logistic regression model to identify women likely to report IPV-related injuries and to validate the model using an independent dataset.

SUBJECTS, MATERIALS AND METHODS

Subjects and study design. To address the research purpose, we implemented a cross-sectional study design approved by the institutional review board of Massachusetts General Hospital, Boston, and enrolled a sample derived from the population of women older than 18 years who sought treatment in the ED for the evaluation and treatment of injuries of nonverifiable etiology (such as falls or assaults). We excluded subjects who sought care for injuries of verifiable etiology—that is, motor vehicle accidents, witnessed assaults or witnessed falls. We also excluded subjects incapable of communication (such as intubated patients), subjects who were unavailable to interview in the ED (such as patients who were in the radiology department at the time of the interview) and those who did not consent to participate in the study. We made interpreters available for women who did not speak English. To ensure a representative sample, we developed a schedule by which we randomly assigned days, times and questionnaire type (described below) to interview subjects in the ED.

Study variables. *Predictor variables.* Exposures of interest included the risk of reporting IPV-related injuries, demographic variables and socioeconomic variables. We stratified risk of reporting IPV-related injuries into high and low categories. To categorize risk, we combined data on two separate variables: injury location and the PVS score. We grouped injury location as HNF or other. The PVS is a brief three-question tool that was developed in an ED setting and has been validated against other well-established questionnaires.[19] It consists of one question that addresses physical violence ("Have you ever been hit, kicked or punched in a relationship?") and two questions that address a woman's perception of her safety ("Have you ever felt unsafe in a relationship?" and "Do you feel safe now?"). A positive response to any of the three questions on the PVS constitutes a positive screen for IPV.[19] The PVS takes 20 seconds to administer orally. (The Massachusetts General Hospital ED uses the PVS as part of nursing triage.[19]) If a subject responded affirmatively to one or more of the PVS questions, we considered it a positive screen for IPV-related injuries.

By combining the two variables, injury location and PVS score, we stratified the risk of reporting IPV-related injuries into two levels: high and low. Subjects classified as having a high risk had HNF injuries and a positive questionnaire screen. We categorized all other combinations of injury location and questionnaire responses as low probability of reporting IPV-related injuries.[17,18]

Outcome variable. The outcome variable was self-reported injury etiology, whether IPV or other. We defined an IPV-related injury as a subject's self-report of an injury secondary to an assault by an intimate sexual partner. Other injury etiologies included assault by a non-partner, sports and occupational injuries and falls.

Other variables. We collected data on two demographic variables: age and race. We recorded age in years at the time of the interview as a continuous variable. We categorized race as white, African-American, Hispanic, Asian or other and assessed it using subjects' self-reports.

We collected data for the following socioeconomic variables and behavioral variables: income, education, marital status, frequency of ED visits and history of substance abuse. We recorded income as a continuous variable. We categorized education as high school or less or some college or postgraduate education. We recorded marital status as married or unmarried. We recorded patients' self-report of the number of ED visits in the previous 12 months as a continuous variable. We recorded a history of substance use—defined as subject's self-report of use of tobacco, alcohol or illicit substances—as a binary variable.

Data analysis. We recorded data for each subject and entered them into a database (SPSS Version 11.0, SPSS, Chicago). To develop and validate the predictive model, we created index and validation sets. We randomly assigned each subject to either the index or validation set in a ratio

of 2:1, respectively. We used the index set of subjects to develop the predictive model and the validation set to assess the predictive model's goodness of fit.

Using the index set, we computed univariate and bivariate statistics to identify associations between the predictor variables and injury etiology. We used predictor variables that were associated statistically or near-statistically ($P \leq .15$) with injury etiology to create a multiple logistic regression model. Using an iterative process, we excluded predictor variables from the model to create the most parsimonious predictive model—that is, a model with the fewest number of variables and largest log-likelihood ratio. We computed odds ratios and associated 95 percent confidence intervals (CI_{95}) for the final predictive model. We considered a P value less than .05 to be statistically significant. To assess the predictive value of the model developed with the index set, we applied it to the validation set. We assessed goodness of fit using the χ^2 statistic, as described by Hosmer and Lemeshow.[25]

TABLE 1

Study variables grouped by index and validation sets.

VARIABLE	INDEX SET	VALIDATION SET	*P* VALUE
Sample Size (n)	201	104	NA*
Age (Years)†	45.2 ± 19.5	46.7 ± 18.0	.60
Race‡			
White	150 (74.6)	80 (76.9)	
Nonwhite	51 (25.4)	24 (23.1)	.40
Marital Status‡			
Yes	105 (52.2)	52 (50)	
No	96 (47.8)	52 (50)	.41
Income ($ per Year)†	42,567 ± 22,820	40,240 ± 17,999	.37
Education‡			
High school	87 (43.3)	54 (51.9)	
College/postgraduate	114 (56.7)	50 (48.1)	.10
Emergency Department Visits/Year‡			
None	61 (30.3)	31 (29.8)	
One or more	140 (69.7)	73 (70.2)	.52
Substance Abuse‡			
Yes	100 (49.8)	58 (55.8)	
No	101 (50.2)	46 (44.2)	.20
Injury Location‡			
Head/neck/facial	63 (31.3)	24 (23.1)	
Other	138 (68.7)	80 (76.9)	.08
Questionnaire Response‡			
Positive for intimate partner violence (IPV)	70 (34.8)	30 (28.8)	
Negative for IPV	131 (65.2)	74 (71.2)	.18
Risk of Self-Reported IPV‡§			
High	37 (18.4)	13 (12.5)	
Low	164 (81.6)	91 87.5)	.07
Self-Reported IPV Injury Etiology‡§			
Yes	20 (10)	8 (7.7)	
No	181 (90)	96 (92.3)	.23

* NA: Not applicable.
† Mean ± standard deviation.
‡ n (%).
§ Subjects with nonzero Partner Violence Screen scores and head, face or neck injuries were classified as having a high risk of reporting IPV-related injury. Subjects with any other combination of questionnaire scores and injury location were classified as being at low risk.

RESULTS

Between November 2001 and May 2005, we screened 328 women for potential study participation. Twenty-three women (7 percent) declined. There were no significant differences with respect to the demographic data between the subjects who enrolled and those who did not elect to enroll. The final study cohort was composed of 305 women, of whom we randomly assigned 201 to the index sample and 104 to the validation sample. Table 1 summarizes the bivariate associations between the predictor variables and the index and validation samples. The racial distribution of the sample was predominantly white (75.4 percent), with smaller representations of African-American (7.1 percent), Hispanic (9.6 percent), Asian (4.7 percent) and other (1.9 percent) groups. As the sample sizes of the nonwhite groups were too small for a meaningful analysis, we recoded race as white and nonwhite. The index and validation samples were not statistically different for any of the study variables ($P \geq .07$).

Table 2 summarizes study variables of the index set grouped by the self-reported injury etiology. The frequency of IPV-related injuries was 10 percent. IPV-related injuries were associated statistically with age, race and risk of reporting an IPV-related injury ($P = .01$) and associated

near-statistically with substance abuse (P = .11) and education (P = .09). We included these five variables in the initial multivariate logistic regression model. We dropped substance abuse history and education from the model, leaving age, race and risk of self-report of IPV-related injury in the final predictive model (Table 3). In the adjusted model, race, risk of self-report of IPV-related injury and age were associated statistically with injury etiology. Nonwhites were 3.7 times more likely to report IPV-related injuries than were whites. Subjects classified as being at high risk were 10.4 times more likely to report IPV-related injuries than were subjects classified as being at low risk. Younger patients were more likely than older patients to report IPV-related injuries.

Table 4 compares the observed versus predicted frequencies of IPV-related injuries. The overall accuracy of the model was 93 percent. When we applied the predictive model to the validation sample, we found excellent agreement between the observed and predicted number of women with IPV-related injuries, as evidenced by the accuracy (93 percent) and the assessed goodness of fit (P = .64, Hosmer-Lemeshow test). A P value of .64 suggests that there was no statistically significant difference between the predicted and observed outcomes.

TABLE 2

Study variables of the index set (n = 201) grouped by injury etiology.

VARIABLE	ETIOLOGY OF INTIMATE PARTNER VIOLENCE (IPV)		*P* VALUE
	Yes	No	
Sample*	20 (10)	181 (90)	NA†
Age (Years)‡	31.2 ± 13.9	46.7 ± 18.4	.01
Race*			
White	6 (30)	144 (79.6)	
Nonwhite	14 (70)	37 (20.4)	.01
Marital Status*			
Yes	8 (40)	97 (53.6)	
No	12 (60)	84 (46.4)	.18
Income ($ per Year)‡	37,750 ± 17,657	43,099 ± 23,299	.32
Education*			
High school	12 (60)	75 (41.4)	
College/postgraduate	8 (40)	106 (58.6)	.09
Emergency Department Visits/Year*			
None	7 (35)	54 (29.8)	
One or more	13 (65)	127 (70.2)	.40
Substance Abuse*			
Yes	7 (35)	94 (51.9)	
No	13 (65)	87 (48.1)	.11
Injury Location*			
Head/neck/facial	17 (85)	46 (25.4)	
Other	3 (15)	135 (74.6)	.01
Questionnaire Response*			
Positive for IPV	13 (65)	87 (48.1)	
Negative for IPV	7 (35)	94 (51.9)	.11
Risk*			
High	16 (80)	21 (11.6)	
Low	4 (20)	160 (88.4)	.01

* n (%).
† NA: Not applicable.
‡ Mean ± standard deviation.

DISCUSSION

The long-term objective of our research efforts is to identify factors associated with an IPV-related injury. As IPV is a chronic recurrent disease, early diagnosis and referral for intervention may interrupt the cycle of violence.[12, 24,26-28] The purpose of this study was to develop and validate a predictive model to identify women likely to report IPV-related injuries. We hypothesized that injury location and responses to a screening questionnaire could be used to stratify risk of self-report of IPV. In addition, we hypothesized that risk of IPV-related injuries may be associated with other variables, such as age, race or marital status.

In brief, using the index dataset of 201 subjects, we identified three variables associated with women who reported IPV-related injuries: risk of self-report, age and race. Subjects categorized as being at high risk had an adjusted 10.4-fold increased risk of self-report of IPV-related injuries when compared with subjects categorized as being at low risk (P = .01). Age and race also

TABLE 3

Multivariate regression model to evaluate predictor variables of model set versus outcome as an IPV*-related injury etiology.

PREDICTOR VARIABLE	ODDS RATIO	95% CONFIDENCE INTERVAL	*P* VALUE
Age†	0.9	.89-.99	.01
Race‡	3.7	1.2-12.0	.01
Risk§	10.4	3.2-34	.01

* IPV: Intimate partner violence.
† Age: As age increases, the likelihood of reporting IPV-related injuries decreases.
‡ Race: White is the reference category and is compared with nonwhite. Nonwhite women are 3.7 times more likely than white women to report IPV-related injuries.
§ Risk: Low risk is the reference category; subjects coded as being at high risk were 10.4 times more likely to report IPV-related injuries than subjects coded as being at low risk.

TABLE 4

A comparison of the outcomes predicted by the model (expected outcome) versus observed outcomes in the index set.*†

EXPECTED OUTCOME: IPV‡-RELATED INJURY	OBSERVED OUTCOME: IPV-RELATED INJURY			
	Yes	No	Total	Percentage Correct
Yes	9	11	20	45
No	4	177	181	98
TOTAL	13	188	201	93

* *P* = .64 (computed using the Hosmer-Lemenshow goodness-of-fit test).
† Overall model accuracy: 93 percent.
‡ IPV: Intimate partner violence.

were associated with likelihood of self-reported IPV-related injuries in the adjusted multivariate model. Older subjects were less likely than younger subjects to report IPV-related injuries. Nonwhite subjects were almost four times more likely than their white counterparts to report IPV-related injuries.

To assess the validity of the predictive model developed using the index dataset, we applied the model to an independent or validation dataset composed of 104 subjects. There was excellent agreement between the predicted and observed percentage of women reporting IPV-related injuries; the accuracy was 93 percent (*P* =.64, Hosmer-Lemeshow goodness-of-fit test).

Our findings of age as a predictor variable for IPV are consistent with those of other studies, in which younger women had an increased risk of experiencing IPV-related injuries when compared with older women.[6,16,20,26,27,29] A large-scale survey by the National Crime Victimization Survey of the U.S. Justice Department found that women aged 19 to 29 years were more likely than other women to be victims of IPV.[20,28]

Race is reported variably in other studies as a risk factor for IPV. Several studies have shown that black and Hispanic women sustain a higher frequency of IPV than do white women.[7,14,19,20,22,28] Retrospective correlation analysis has determined that the prevalence rate of IPV is predicated on ethnicity and low socioeconomic status.[30]

Several variables in our study were not associated with IPV: frequency of ED visits during the past year, tobacco or alcohol abuse, education or income. Other researchers found an association between substance abuse and income and IPV.[24,28-30] Changes in lifestyle such as loss of employment by either the perpetrator or victims may increase the risk of experiencing an IPV-related injury.[1,6,16,29] Foster and colleagues[30] found that decreased income, lack of a high-school education and race/ethnicity were significantly related to current abuse and abuse during pregnancy.[30] Differences between these studies and ours may be attributed to the sociodemographics of our population, as well as to how the questions are being interpreted by the subjects. We are re-addressing these other risk factors using the proposed model to determine if these predictors further increase the risk of IPV in our study population.

A near-universal problem in researching IPV is the issue of misclassification of the outcome variable of injury etiology. As injury etiology is based on subjects' self-reports, absent an independent objective way to confirm an injury's etiology, it is quite possible that some subjects with IPV-related injuries will report that the injury has other etiologies, such as a fall. Misclassification produces two major errors: false positives and false negatives. A false positive would be defined as a patient's self-report of injury due to IPV

when in fact the etiology was something other than IPV. False-positive errors occur only rarely.[13,14] A false negative would be defined as a patient's self-report of an injury that was due to IPV as being caused by some other factor. This error occurs more commonly.[13,14,24] One consequence of misclassification is a significant increase in false-negative findings. The net effect of having predominantly one type of misclassification error (more false negatives than false positives) is an underestimation of the true sensitivity of the diagnostic protocol, and it should have minimal effect on the specificity estimates.

CONCLUSION

A predictive, validated model composed of three elements—risk of self-report of IPV-related injury, age and race—was associated with women who reported IPV-related injury in the ED setting. We hypothesize that these three unambiguous, readily assessed variables could be used to develop a protocol to facilitate the early diagnosis of IPV. Once IPV-related injury is diagnosed, dental professionals may initiate intervention efforts to prevent future IPV-related injuries. ■

Funding for the study described in this article was contributed by Harvard Medical School Center of Excellence in Women's Health, Boston; the Oral and Maxillofacial Surgery Foundation, Rosemont, Ill.; and the Department of Oral and Maxillofacial Surgery Education and Research Fund, Massachusetts General Hospital, Boston.

This article is offered as a resource tool; it is not intended to set specific standards of care, or to provide legal or other professional advice. The practices described in the article should be conducted in accordance with applicable law, including state law regarding scope of practice, reporting obligations and referral options.

The authors thank Michelle Finkel, MD; Srinivas Susarla, predoctoral student at the Harvard School of Dental Medicine, Boston; and Blair Parry, research assistant, and the other staff members of the Massachusetts General Hospital Emergency Department, Boston, for their ongoing support of and encouragement in this research endeavor.

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