Exploring Structural Relationships Between Blood Alcohol Concentration and Signs and Clinical Assessment of Intoxication in Alcohol-Involved Injury Cases

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Abstract — Aims: Although the relationship between the Y90 (blood alcohol concentration, BAC) and Y91 (clinician intoxication assessment) ICD-10 codes has received attention recently, the role of 10 signs of intoxication in the Y91–Y90 relationship has not been studied yet. This work examines these signs in the estimation of alcohol intoxication levels of patients in medical settings. Methods: Collected and analyzed were data on 1997 injured emergency room patients from 17 countries worldwide reporting drinking prior to injury or presenting with a non-zero BAC from 17 countries worldwide. A model is estimated describing how the 10 signs inform the Y91, Y90 prediction with the goal of the use of observations on patients in place of a biological measure. Results: Signs were consistent with a single underlying construct that strongly predicted Y91. Smell of alcohol on breath predicted Y90 above its contribution through the construct and was stronger for those with tolerance to alcohol than for those without. Controlling for Y91, no sign further contributed to prediction of Y90 indicating that Y91 incorporated all intoxication sign information in predicting Y90. Variance explained was high for Y91 (R² = 0.84) and intoxication signs (above 0.72 for all but smell on the breath, 0.57) and lower for Y90 (0.38). Conclusion: Intoxication assessments are well predicted by overall intoxication severity, which itself is well represented by intoxication signs along with differential emphasis on smell of alcohol on breath, especially for those with alcohol tolerance. However, BAC levels remain largely unexplained by intoxication signs with a clinician’s assessment serving as the primary predictive measure.

INTRODUCTION

The causal role of alcohol in injuries has been well established (Rehm et al., 2010), a result due largely to improvements in reporting and documentation efforts. One example of this effort was the addition of the Y90 (BAC) and Y91 (clinical assessment of intoxication) alcohol intoxication codes to ICD-10 (Room, 1982; Grant et al., 1987; World Health Organization, 1992a), the international standard for the systematic recording, analysis, interpretation and comparison of mortality and morbidity data cross-culturally over time (World Health Organization, 1992b).

The Y90 code serves as a biological measure, typically collected from breath or blood samples, of the concentration of ethanol in a subject. In contrast, Y91 serves as a subjective evaluation of clinical signs and levels of impairment of a subject’s physiological, mood and functional responses, typically assessed by a trained clinician. Together, the Y90 and Y91 codes were appended to the ICD-10 ‘external causes’ chapter as categories to be used as supplementary information considering the causes of morbidity and mortality with commentary implying that Y91 code could be used as a backup when Y90 could not be coded. Although Y91 is collected from subjective assessment, each Y91 category is instructed by brief text indicating example intoxication signs and corresponding severity levels relevant to the overall assessment level. However, the extent to which clinicians follow these guidelines or whether detailed severity data for each sign might better inform BAC levels has not been studied yet. Furthermore, in addition to factors such as gender and age, known to influence the processing of ethanol in the body, the observable responses may also be heavily affected by acclimation to the intoxicating effect of heavy alcohol use (Gmel et al., 2006).

Although intoxication assessment in medical settings is the focus here, it is clearly not the only important in such an assessment, the others being roadside assessment by law enforcement (Perrine et al., 1993) and responsible beverage service (Saltz, 1997). Although it may be desirable to have standardized methods for such an assessment, the associated logistics (e.g. roadside at night or in a dark bar, compared with a medical office) may require differential emphasis across various intoxication signs. For example, studies of the relationship between BAC levels and roadside evaluations of drivers have found, even controlling for BAC level, a dramatic range in an individual’s functioning, likely a result of a number of factors including tolerance to the effects of heavy alcohol use, training of the person evaluating the subject and usage of other substances (Penttilä and Tenhu, 1976).

Toward the establishment of ICD-11, current discussions of ICD-10 revisions have identified interest regarding the usefulness of the Y90 and Y91 codes as interchangeable measures of alcohol intoxication when used in alcohol-related injury research in ER settings. Only a single prior study (Cherpitel et al., 2005) has attempted to study the relationship between the two codes. Using data from 12 countries comprising the WHO Collaborative Study on Alcohol and Injuries (World Health Organization, 2007) (a subset of the data analyzed in the present work), this study was restricted to simply examining overall and subgroup agreement of the two categorical measures, finding agreement to only be modest. Further, the role of clinical signs of intoxication, which represent a larger response burden than the Y90 and Y91 codes, was not examined in this study. The present study examines the role of intoxication signs in the relationship between Y91 and Y90 to assess the relative contributions of individual signs to clinicians’ formulation of Y91 coding and whether individual signs contain additional information over and above the shared contribution of the combined set of signs that would better inform prediction of Y91. Additionally, as alcohol tolerance has been identified as an important factor regarding the degree to which some intoxication signs are expressed,
analyses were also conducted separately by whether the respondent reported tolerance to the effects of alcohol.

METHODS

Sample

The data include ER samples from 17 countries (Public Health Institute IRB #102–004), each collected using a similar methodology and including patients arriving within 6 h of the injury event leading to the ER visit (Cherpitel et al., 2003, 2012; WHO Collaborative Study Group, 2005). Data were collected in 2001–2002 (South Africa, Mozambique, Switzerland, Sweden, India, Czech Republic, Belarus, China, Argentina, Brazil, Mexico), 2010–2011 (Dominican Republic, Guatemala, Guyana, Nicaragua, Panama), 2006–2007 (Switzerland) and 2009 (Korea). For each study, a probability sampling design was implemented that equally represented each 8-h shift for each day of the week. Injury patients 18 years of age or older were selected from ER admission forms, including walk-in patients as well as those arriving by ambulance, and reflected consecutive ER arrivals. Once selected and as soon as possible after admission to the ER, patients were approached with an informed consent to participate. Trained interviewers collected BAC estimates via breath samples using an Alco-Sensor III intoximeter, which has been found to provide estimates that are highly correlated with chemical analysis of blood (Gibbs, 1983). Clinical intoxication assessment was performed by an ER physician/nurse as close to the ER admission time as possible. In most cases, the clinical assessment of intoxication was completed prior to the BAC reading and the clinicians completing the assessment were blind to the BAC estimate.

Measures

To facilitate the definition and application of the Y91 clinician intoxication assessment, ten specific biological and physiological/mood function/response signs of intoxication were first coded by the physician/nurse directly observing the patient. The signs included smell of alcohol on breath, conjunctival injection/flushed face, horizontal gaze nystagmus, speech impairment, motor coordination impairment, attention/judgment impairment, elated/depressed mood, behavioral response disturbances, emotional response disturbances and cooperation impairment. Response categories for each were initially collected on a 1 (none)-to-5 (very severe) scale (distributions shown in Table 2).

Y91 codes patient intoxication into five levels, each provided with a short description based on example signs and corresponding severity levels. These levels are: (a) not intoxicated; (b) mild (Y91.0): smell of alcohol on breath, slight behavioral disturbance in functions and responses or slight difficulty in coordination; (c) moderate (Y91.1): smell of alcohol on breath, moderate behavioral disturbance in functions and responses or moderate difficulty in coordination; (d) severe (Y91.2): severe disturbance in functions and responses, severe difficulty in coordination or impaired ability to cooperate and (e) very severe (Y91.3): very severe disturbance in functions and responses, very severe difficulty in coordination or loss of ability to cooperate. Although these descriptions generally serve as a guide to clinicians, they do not define a unique intoxication assignment algorithm, leaving considerable leeway for clinicians (e.g. differential weighting of signs, combinations of severities across signs). An additional item assesses whether the clinician believes there is any evidence of substance usage other than alcohol.

The Y90 sub-codes categorize continuous BAC into a series of nine groups, defined as: <20 mg/100 ml (Y90.0); 20–39 mg/100 ml (Y90.1); 40–59 mg/100 ml (Y90.2); 60–79 mg/100 ml (Y90.3); 80–99 mg/100 ml (Y90.4); 100–119 mg/100 ml (Y90.5); 120–199 mg/100 ml (Y90.6); 200–239 mg/100 ml (Y90.7) and ≥240 mg/100 ml (Y90.8). A small number of cases (<1%) were assigned to Y90.9 (presence of alcohol in blood, level not specified) and were removed from analyses.

Two additional measures were utilized in the present analyses. First, a measure of tolerance to the effects of alcohol in the past 12 months was also collected and asked as ‘In the past 12 months, have you found that you need to drink much more than before to get the same effect or that drinking your usual amount began to have less of an effect on you?’ Second, clinicians indicated whether there was evidence of any substance usage other than alcohol and those subjects for which evidence was present were removed from analyses.

Analyses

Due to strong skewness of the original five-category Y90 and Y91 measures, each was recoded into three severity levels (none, mild, moderate/severe/very severe) for analysis. Doing so avoids model empirical identification problems common to the analysis of multivariate categorical outcomes that were encountered in preliminary model estimation. For Y91 and sign data, the three highest levels were combined to form response categories of none, mild and moderate/severe/very severe. For Y90, the 3 category variable used in analyses was defined as 0–0.009, 0.01–0.799 and 0.08+. Model estimation was confined to the sample who either reported drinking 6 h prior to injury or presented to the ER with a positive BAC for whom there was no sign of other substance use. The use of such a sample precludes dilution of findings resulting from the inclusion of a large number of cases with homogeneous (i.e. negative for alcohol use) responses to each of the variables under study. This allows analyses to focus on the more relevant sample of those for which any of several measures of drinking (and not drug use) indicated that alcohol was consumed.

An exploratory factor analysis (EFA) was first conducted to examine the underlying dimensional structure of the 10 clinical intoxication signs. After confirming the unidimensionality, a confirmatory factor analysis (CFA) model was estimated, the significant paths for which are shown in Fig. 1. The estimated model assumes that a 1-dimensional latent intoxication severity factor (the circle in the figure) underlies and generates intoxication sign data. Further, this latent factor manifests itself to clinicians generating Y91. Although signs are each allowed to play a differential role in the empirical definition of overall intoxication severity (through varying factor loadings), they may further contribute to a clinician’s assessment via direct effects on Y91. Finally, Y90 is included as a dependent variable predicted from Y91, the overall latent severity and direct effects from individual intoxication signs. As a parsimonious approach to estimation of this model, these direct effects are examined using modification indices (MI) and included only when significant. Model fit was assessed using fit indices.
including the comparative fit index (CFI), Tucker-Lewis fit index (TLI) and root mean square error of approximation (RMSEA). Analyses were performed using SPSS (SPSS, Inc., 2009) and Mplus (Muthén and Muthén, 2011).

RESULTS

Table 1 shows the sample distribution across countries. Although distributions of each of the original intoxication signs, Y90 and Y91 were strongly skewed (not shown), combining the top 3 categories (moderate, severe and very severe) resulted in more evenly spread overall distributions (Table 2). EFA results performed on the trichotomous sign indicators strongly supported a single underlying dimension (first, second eigenvalues = 8.98, 0.30,...). Although sign loadings on the first factor were each 0.90 and above, loadings for smell, face flushing and horizontal gaze nystagmus were the lowest of the ten and loadings for these three items on the second factor were far larger than all others.

The CFA model in Fig. 1 was then estimated. Initially, only those paths with solid lines were estimated as part of the model (each significant, \( P < 0.001 \)). The fit of the resulting model was only moderate (CFI = 0.97, TLI = 0.97, RMSEA = 0.16) with two omitted paths with very large (>100) MI statistics (dashed lines). These paths included a direct effect from smell to Y91 and a residual correlation between smell of alcohol and flushed face. The threshold parameter estimate for the smell indicator was the lowest across signs (with thresholds for flushing the second lowest, results not shown), indicating that smell was one of the most prevalent signs observed, hence providing information on intoxication severity at the lower end of the spectrum.

After inclusion of these two paths, model fit improved substantially (CFI = 0.99, TLI = 0.99, RMSEA = 0.08) with only a few further paths with marginally significant MIs indicating (a) residual correlations among sign indicators and (b) paths representing relationships between three of the signs and the Y91 measure. The former of these two types of paths represents relationships with less substantive interest; significance levels for the latter were only marginal and with the sensitivity of the MIs to the large sample sizes and the lack of improvement in model fit obtained from including paths of either type, no further paths were included. Noteworthy is that controlling for Y91, there was no direct effect of the latent intoxication factor nor of any individual sign in the prediction of Y90.

Acknowledging the role that alcohol tolerance may have on the presentation of several of the signs, analyses were conducted on the subsample of those reporting \((n = 278)\) and, separately, not reporting alcohol tolerance \((n = 1616)\). Higher BAC levels were observed for those reporting alcohol tolerance than for those not (average BAC = 0.013, 0.008 mg/dl, respectively, \( P < 0.001 \)). For both samples, an omitted path from smell to Y91 produced an MI at least twice as large as the next largest; for the subsample with tolerance, this MI was
10 times that of the sample without tolerance. However, as the MIs are known to be sensitive to sample size, a random subsample of the non-tolerant sample was selected of the same size as the sample indicating tolerance. For this subsample, estimated MIs were substantially smaller than for the full non-tolerant sample with the MI for the path from smell to Y91 again producing the dominant MI. Additionally, for the tolerant sample with the MI for the path from smell to Y91 estimated MIs were substantially smaller than for the full non-tolerant sample. For this subsample, MIs are known to be sensitive to sample size, a random subsample without tolerance, the MI was only half the size as the sample indicating tolerance. For this subsample, the sample of the non-tolerant sample was selected of the same size as the sample indicating tolerance. As the sample without tolerance, the MI was estimated to be 0.57, indicating the presence of some shared, albeit small, item variance not represented in other sign indicators. Although not indicating an empirically distinct component of intoxication, such a finding is consistent with a differentiation of intoxication signs whose expression drinkers can vs. cannot adapt through repeated exposure to heavy drinking (American Prosecutors Research Institute (APRI), 2003).

A second finding was that the latent intoxication severity factor was a strong predictor of Y91. Additionally, above its contribution through the intoxication factor, smell also had a significant positive direct effect on Y91. This result indicates that controlling for severity of intoxication, clinicians appeared to have not relied enough on smell as prediction of Y91 improved when more emphasis in the formulation of Y91 was allotted to this sign. The intoxicating influence of an acute heavy drinking event is influenced by one’s history of heavy alcohol use, and prior work has found that controlling for level of alcohol use, risk of injury associated with an acute binge drinking event is lower among those with a history of chronic heavy drinking compared with those without (Gmel et al., 2006). It seems reasonable that one mechanism behind such a result is the respondent’s acclimation to the effects of alcohol use, likely observable in one or more intoxication signs. Analyses indicating a stronger need for a direct effect of alcohol smell predicting Y91 for those with vs. without tolerance indicates that intoxication severity is underestimated for those with tolerance; thus, better predictions of Y91 are obtained by placing additional emphasis on smell when other signs may indicate less severe intoxication. Clearly, for those with alcohol tolerance, it seems reasonable that a clinician may rely more strongly on intoxication signs that cannot be masked through physiological or psychological adaptation (i.e. smell, face

<table>
<thead>
<tr>
<th>Level</th>
<th>Clinician assessment</th>
<th>BAC</th>
<th>Intoxication signs</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>Y91 33.9</td>
<td>Y90 27.0</td>
<td>Smell 31.1</td>
</tr>
<tr>
<td>Mild</td>
<td>37.9</td>
<td>38.3</td>
<td>33.8</td>
</tr>
<tr>
<td>Moderate+</td>
<td>28.2</td>
<td>34.7</td>
<td>35.1</td>
</tr>
</tbody>
</table>

| Factor loadings | 0.91 | 0.92 | 0.89 | 0.96 | 0.96 | 0.97 | 0.94 | 0.97 | 0.96 | 0.96 |

Table 3. Variance explained in CFA model*

<table>
<thead>
<tr>
<th>Intoxication Signs</th>
<th>$R^2$</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smell</td>
<td>0.57</td>
<td>0.02</td>
</tr>
<tr>
<td>Flush</td>
<td>0.72</td>
<td>0.02</td>
</tr>
<tr>
<td>Gaze</td>
<td>0.74</td>
<td>0.02</td>
</tr>
<tr>
<td>Speech</td>
<td>0.84</td>
<td>0.01</td>
</tr>
<tr>
<td>Motor</td>
<td>0.88</td>
<td>0.01</td>
</tr>
<tr>
<td>Judgment</td>
<td>0.92</td>
<td>0.01</td>
</tr>
<tr>
<td>Mood</td>
<td>0.84</td>
<td>0.01</td>
</tr>
<tr>
<td>Behavior</td>
<td>0.92</td>
<td>0.01</td>
</tr>
<tr>
<td>Emotion</td>
<td>0.86</td>
<td>0.01</td>
</tr>
<tr>
<td>Cooperation</td>
<td>0.87</td>
<td>0.01</td>
</tr>
<tr>
<td>Y91—Clinical Assessment</td>
<td>0.84</td>
<td>0.01</td>
</tr>
<tr>
<td>Y90—BAC</td>
<td>0.38</td>
<td>0.03</td>
</tr>
</tbody>
</table>

*Drunk 6 h prior to injury or + BAC.

Analyses examining the role of intoxication signs in the relationship between Y91 and Y90 revealed several important findings. The first is that the underlying construct measured by signs is largely unidimensional. However, factor loadings for smell, flushing and gaze on the first dimension were slightly lower and the second dimension of a two-factor rotated solution was dominated by these three items (with small loadings for these items on the first dimension), indicating the presence of some shared, albeit small, item variance not represented in other sign indicators. Although not indicating an empirically distinct component of intoxication, such a finding is consistent with a differentiation of intoxication signs whose expression drinkers can vs. cannot adapt through repeated exposure to heavy drinking (American Prosecutors Research Institute (APRI), 2003).

Given the sample heterogeneity regarding drinking cultures that may affect the expression/recognition of some signs (e.g. behavioral, mood but not smell or nystagmus) (MacAndrew and Edgerton, 1969), analyses were also conducted separately for each of three levels of detrimental pattern of drinking (DDP) of a country. The DDP measure is a composite constructed from proportion of abstainers in a country, proportion of drinking occasions in which heavy drinking occurs, proportion of drinking occasions in which drinkers get ‘drunk’, proportion of drinking occurring with meals and how common drinking is in public places (Rehm et al., 2003). However, similar results were found across each of the DDP levels as observed for the combined sample (results not shown). Analyses were also conducted separately by gender with no differential findings.

Estimated $R^2$ values are shown for each dependent variable in Table 3. The latent intoxication severity factor explained the majority of the variability in each of the signs ($R^2 = 0.72–0.92$) except for smell ($R^2 = 0.57$), with similar variance explained for Y91 (0.84) and lower variance explained for Y90 (0.38). $R^2$ estimates for Y90 were somewhat lower for the sample with tolerance (0.21) compared with the random subsample selected of those without (0.30).

DISCUSSION

Analyses examining the role of intoxication signs in the relationship between Y91 and Y90 revealed several important findings. The first is that the underlying construct measured by signs is largely unidimensional. However, factor loadings for smell, flushing and gaze on the first dimension were slightly lower and the second dimension of a two-factor rotated solution was dominated by these three items (with small loadings for these items on the first dimension), indicating the presence of some shared, albeit small, item variance not represented in other sign indicators. Although not indicating an empirically distinct component of intoxication, such a finding is consistent with a differentiation of intoxication signs whose expression drinkers can vs. cannot adapt through repeated exposure to heavy drinking (American Prosecutors Research Institute (APRI), 2003).

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flushing). This is further supported by the finding indicating a need for a residual correlation between smell and flushing, especially given that flushing was more correlated with smell (0.86) than any other sign (all other correlations <0.72, results not shown).

Finally, in predicting Y90, results indicated that neither the intoxication severity itself nor individual sign data provided additional information beyond Y91. However, unlike Y91 and intoxication signs for which \( R^2 \) estimates were high, the low \( R^2 \) for predicting Y90 indicated that the majority of variation in BAC remained unexplained. Several reasons might explain this finding. One may be that the model estimated simply fails to capture the complexity of the true relationships between the variables studied. Another may be that given instructions for each Y91 level roughly indicated the appropriate corresponding severity levels of signs, all relevant variability in sign data for predicting Y90 had already truly been incorporated into the clinician’s assessment. Further, clinicians may use additional information beyond that examined here (e.g., knowledge of subject-specific behaviors). Although results from sample size-adjusted analyses performed separately across alcohol tolerance status seemed to suggest that smell should play a larger independent role in a clinician’s assessment for tolerant compared with non-tolerant samples, for neither sample did signs predict Y90 after controlling for Y90. Finally, the low \( R^2 \) for Y90 indicates that although clinicians do a relatively poor job of identifying intoxication level, there does not appear to be any more information (at least for the specific model proposed here) in the signs that might help them improve their assessment.

A number of limitations of the present study should be acknowledged. One is that the sample analyzed represents some groups for which some signs may be differentially influenced by genetics (e.g., face flushing in Asian populations). Another potential limitation may have arisen from the lack of precision resulting from the need to collapse the categorical severity measures from five to three severity levels. Although this re-categorization clearly removes the ability to capture fine-grained information distinguishing higher intoxication levels, model estimation was not possible given the sparseness of the resulting multivariate distribution of these categorical variables. The tolerance measure used may also be problematic in that it is self-reported by the respondent and thus is both subjective and may be influenced by drinking culture. Finally, although those subjects who clinicians believed used any substance other than alcohol were removed from the present analyses, signs of usage of some substances (especially at low levels) are not dissimilar from those produced from alcohol use and thus may not have been accurately detected and may have enhanced expression of some intoxication signs.

Clearly, as summarized by Touquet (2005), ‘clinical assessment is difficult’. For purposes concerned more with gross than with minor misclassification, Cherpetil et al. (2005) provided reassurances finding that only a small proportion (1.1%) of those with BAC of 0.10% or above were assessed as not intoxicated and 0.5% were negative on BAC but assessed as moderately or severely intoxicated. However, the relatively weak relationship between Y91 and Y90, found both here and in prior work, remains. One suggested reason for this finding is that the two codes ‘are not measuring the same dimension: that, looking across a population of drinkers, behavioral signs of intoxication are not very highly correlated with BAC’ (Room, 2012). Results from the present work seem to partially support this distinction in the intoxication signs, finding consistent, albeit weak, support for a second dimension as indicated by alcohol smell, face flushing/conjunctival injection and gaze nyctagmus. However, the independent contribution of smell to the prediction of Y91, especially for those with alcohol tolerance, alternatively suggests that a clinician’s assessment does indeed adapt depending to indications of a patient’s experience with alcohol.

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