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Original Article

Trauma center risk conditions for blood alcohol-positive and alcohol misuse patients: a retrospective study

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Abstract: Because few studies have assessed blood alcohol concentration (BAC)-positive risk conditions in trauma activation patients, this retrospective investigation pursued such an analysis. The parent database included consecutive trauma center admissions from January 21 to July 21 for 2018-2020. The supplementary electronic medical record audit of trauma activation patients aged 18-60 years (TA18-60) assessed alcohol misuse, smoking history, and serum bicarbonate levels. An alcohol misuse risk score was created by assigning a value of 0 (no) or 1 (yes) for each risk condition: 1) smoking history, 2) BAC-positive status, 3) BAC ≥ 100 mg/dL with Glasgow Coma Scale score (GCS) ≥ 13, 4) age ≥ 40 years, and 5) bicarbonate level ≥ 20 mmol/L in BAC-positive patients and summing the total score (range, 0-5). Of 2,076 patients, BAC testing occurred in 60.9% (n = 1,265). BAC positivity was greater in TA18-60 (36.9%) than in other patients (20.8%; $P < 0.0001$; odds ratio [OR] = 2.2). In the TA18-60 audit (n = 742), categorizations were available for BAC status, 98.5%; smoking history, 99.3%; alcohol misuse history, 99.5%; and bicarbonate level, 99.5%. BAC positivity was greater in smokers (41.3%) than in non-smokers (31.5%; $P = 0.0061$; OR = 1.5). BAC positivity was greater with alcohol misuse (87.0%) than without (17.7%; $P < 0.0001$; OR = 31.2). BAC-positive was associated with a greater proportion of bicarbonate levels < 20 mmol/L (52.0%) than BAC-negative (31.8%; $P < 0.0001$; OR = 2.3). The alcohol misuse proportion was greater with an alcohol misuse risk score of 3-5 (74.4% [142/191]) than with a risk score of 0-2 (10.4% [57/546]; $P < 0.0001$; OR = 24.9; area under the receiver operating characteristic curve = 0.89). This retrospective study demonstrates that BAC positivity is associated with TA18-60, smoking and alcohol misuse histories, and metabolic acidosis. An alcohol misuse history is associated with multiple risk conditions. Trauma center leadership should provide procedures to identify patients who are BAC-positive or have a positive smoking or alcohol misuse history. Then, such patients should be referred to care providers who can offer assistance and guidance for enhancing overall patient wellbeing.

Keywords: Trauma centers, alcohol misuse, blood alcohol content

Introduction

Trauma activation risk conditions for blood alcohol concentration (BAC)-positive publication results are few. We sought to perform a supplementary electronic medical record (EMR) audit to elaborate on potential risk conditions for BAC positivity in young trauma activation patients. Literature evidence was found suggesting that potential trauma BAC-positive associations might exist for alcohol misuse [1-3] and metabolic acidosis [4, 5]. Additionally, we wanted to retrospectively assess the relationship between smoking and BAC positivity because a smoking history has been associated with hazardous alcohol consumption [6-8]. We made the following hypotheses. 1) Younger trauma activation patients would have higher BAC-positive proportions than other patients. 2) BAC-positive proportions in the younger trauma activation patients would have associations with smoking, alcohol misuse, and metabolic acidosis. 3) An alcohol misuse history would have associations with a positive smoking history, positive blood alcohol test result, age ≥ 40 years, the absence of metabolic acidosis with a blood alcohol-positive finding, and cognitive preservation despite intoxication.

Patients and methods

Ethics statements

The current retrospective study was approved by the local institutional review board (approval number: 22-003). The need for informed consent was waived because of the retrospective design and the board decision that the research involved no more than minimum risk to the study population.

Literature search

A search within the National Library of Medicine for articles that include "trauma and alcohol" or "trauma and ethanol" in the title revealed > 200 publications regarding human-related traumatic injuries. Related to our interests, studies have examined BAC testing and BAC-positive proportions from four trauma cohorts collected in 2009, 2015, 2019, and 2020 that included a total of 1,247,988 patients [9-11]. None of the four studies focused solely on trauma activation patients. Using combined random effect analyses, the overall BAC testing proportion for these four investigations was 38.4% (95% confidence interval [CI]: 35.1-41.8%), and the overall BAC-positive proportion was 35.9% (95% CI: 32.3-39.7%) [9-11]. A 40% BAC testing proportion and a 33% BAC-positive proportion raises the question as to which patients should undergo BAC testing.

We identified 14 investigations that described injury and epidemiological associations with BAC-positive trauma patients [4, 12-24]. Only one study focused on trauma activation patients [14]. The literature has shown that trauma activation patients have increased BAC-positive results when compared to trauma consultation patients [25]. In addition, trauma investigations have shown that younger patients have increased proportions of BAC positivity [13, 14]. Therefore, the primary cohort of interest in the current investigation was young trauma activation patients.

Parent database research indicators: trauma activation patients aged 18-100 years

The parent data emanated from an investigation that was used to assess the association of coronavirus disease on trauma outcomes [26]. The database consisted of consecutive patients admitted to a Level I trauma center from January 21 to July 21 for each of the years 2018-2020. Eligible patients were identified through the trauma registry. Included patients were 18 years or older; triaged as a trauma team (high-level acuity), alert (mid-level acuity), or consult (low-level acuity); and admitted to the hospital during the specified time periods. Trauma activation patients were those with high-level or mid-level acuity. Patients were excluded if they were younger than 18 years of age, discharged from the emergency department, did not meet trauma registry inclusion criteria, or were a non-trauma service patient. Data that were obtained from the trauma registry included the Glasgow Coma Scale score (GCS) computed upon trauma center arrival by the trauma physicians, Injury Severity Score (ISS) computed following admission by the trauma registry staff, age, sex, mechanisms of injury documented by the trauma physicians, and trauma activation status (yes or no) documented by the emergency department nursing staff. BAC testing status (yes or no) and test results were obtained by performing an EMR interrogation for each patient. A BAC-positive test result was the detection of a BAC value > 10 mg/dL. The blood sample was routine and was obtained within 15 minutes of trauma center arrival. Cognitive preservation with intoxication was defined as the simultaneous presence of a BAC ≥ 100 mg/dL with GCS ≥ 13.

EMR audit research indicators: trauma activation patients aged 18-60 years

We performed an EMR audit on all trauma activation patients aged 18-60 years in the parent database. Those outside of the aforementioned age range were excluded. The EMR audit assessed the following items: alcohol misuse history, smoking history, and admission serum bicarbonate level. Criteria for a positive alcohol misuse history were evidence of daily drinking or consuming > 7 alcoholic drinks per week or documentation of an alcohol abuse diagnosis. A current alcohol consumption history was obtained from the patient and/or family. The determination of an alcohol abuse diagnosis required the documentation in the EMR during the trauma stay of a diagnosis of alcohol abuse, alcoholism, chronic alcoholic, or alcohol use disorder. When EMR documentation was

sufficient, alcohol misuse history was categorized as yes or no. Smoking history was typically documented in the EMR as never smoked, past smoker, or current smoking history. A positive smoking history was defined as currently smoking ≥ 0.5 packs per day. When EMR documentation was sufficient, smoking history was categorized as yes or no. The bicarbonate level was obtained from the admission arterial blood gas sample or venous chemistry blood sample when an arterial blood gas analysis was not performed. The blood specimens were obtained within 15 minutes of trauma center arrival. When EMR data were present, a bicarbonate level < 20 mmol/L was categorized as yes or no. A bicarbonate level < 20 mmol/L was considered to represent metabolic acidosis. An alcohol-positive risk score was created by assigning a value of 0 (no) or 1 (yes) for each risk condition (smoking history, bicarbonate level < 20 mmol/L, and alcohol misuse history) and summing the total score (range, 0-3). An alcohol misuse risk score was created by assigning a value of 0 (no) or 1 (yes) for each risk condition (smoking history, BAC-positive status, BAC ≥ 100 mg/dL with GCS ≥ 13, age ≥ 40 years, and bicarbonate level ≥ 20 mmol/L in BAC-positive patients) and summing the total score (range, 0-5).

Statistical analysis

Continuous data, such as the BAC, and ordinal rank data, such as the GCS, are expressed as the mean ± standard deviation, while categorical variables are reported as frequency count and percentage. We calculated Cohen d values to evaluate the weight of two intergroup mean differences. For univariate analyses with a dichotomous dependent outcome (yes or no), we analyzed intergroup mean differences using the independent t-test for continuous data and Wilcoxon rank sum test for ordinal rank data. For dichotomous proportional data displayed in a 2 × 2 contingency table format (e.g., BAC-positive [yes or no] and alcohol misuse or smoking history [yes or no]), we used a two-tailed Fisher exact test to analyze the odds ratio (OR). For contingency tables bigger than 2 × 2, we applied the chi-square statistic (e.g., alcohol-positive [yes or no] and > two risk subgroups). We performed multivariate logistic regression analysis (procedure logistic) to evaluate the associations of a dichotomous dependent variable, such as a bicarbonate level < 20 mmol/L (yes or no), with independent variables, such as BAC-positive (yes or no), alcohol misuse (yes or no), and ISS ≥ 20 (yes or no).

We entered the results into Excel 2010 (Microsoft Corp., Redmond, WA, USA) and imported them into SAS System for Windows, release 9.2 (SAS Institute Inc., Cary, NC, USA). For receiver operating characteristic curve analyses, we exported data from SAS into MedCalc® Statistical Software, version 19.2.6 (MedCalc Software Ltd, Ostend, Belgium). We set significance levels for the *p*-value at < 0.05.

Results

Parent group: alcohol associations

In total, 2,076 consecutive trauma admission patients, from January 21 to July 21 for each of the years 2018-2020, were included in the primary analyses. BAC testing occurred in 60.9% (1,265/2,076). Testing proportions were increased in the patients with a GCS 3-14, ISS 21-75, age 18-60 years, male sex, penetrating trauma, and trauma activation (**Table 1**). The overall BAC-positive proportion was 30.1% (381/1,265). Positive proportions were increased in patients with an ISS 21-75, age 18-60 years, and male sex (**Table 1**). Trauma activation patients aged 18-60 years accounted for 35.7% of the total patient admissions and had substantially increased proportions for BAC testing and BAC-positive status (**Table 2**).

EMR trauma activation patients aged 18-60 years audit: variable classifications and comorbidities

Of 742 trauma activation patients aged 18-60 years, the supplementary EMR audit variables were classified according to data availability. An alcohol misuse history was categorized (yes or no) in 738 (99.5%) patients and was positive in 200 (27.1%). A smoking history was categorized in 737 (99.3%) patients and was positive in 366 (49.7%). An admission serum bicarbonate level was found in 738 (99.5%) patients and was < 20 mmol/L in 289 (39.2%).

Trauma activation patients aged 18-60 years audit: BAC-positive associations

Among 731 (98.5%) trauma activation patients aged 18-60 years undergoing BAC testing, the

Table 1. Alcohol-tested and alcohol-positive proportions according to injury traits in the parent cohort

Injury Trait	BAC Tested	Tested %	*p*-value	BAC (+)	BAC (+) %	*p*-value
GCS 3-14	420/533	78.8		140	33.3	
GCS 15	845/1,543	54.8	< 0.0001	241	28.5	0.0789
ISS 1-20	1,047/1,797	58.3		300	28.7	
ISS 21-75	218/279	78.1	< 0.0001	81	37.2	0.0128
Age 18-60 years	872/1,117	78.1		322	36.9	
Age 61-100 years	393/959	41.0	< 0.0001	59	15.0	< 0.0001
Female sex	397/807	49.2		96	24.2	
Male sex	868/1,269	68.4	< 0.0001	285	32.8	0.0019
Blunt injury	1,113/1,911	58.2		334	30.0	
Penetrating injury	152/165	92.1	< 0.0001	47	30.9	0.8182
Consult	246/1,035	23.8		72	29.3	
Activation	1,019/1,041	97.9	< 0.0001	309	30.3	0.7460

Note: BAC, blood alcohol concentration; GCS, Glasgow Coma Scale score; ISS, Injury Severity Score.

Table 2. Comparisons of alcohol testing and positive proportions between patients with trauma activation aged 18-60 and others

Trauma Activation & Aged 18-60 Years	No	Yes	*p*-value	OR
Number	1,334 (64.3%)	742 (35.7%)		
Alcohol tested	534 (40.0%)	731 (98.5%)	< 0.0001	99.6
Alcohol-positive	111 (20.8%)	270 (36.9%)	< 0.0001	2.2

Note: OR, odds ratio.

Table 3. Alcohol-positive proportions according to the number of patients with a smoking history, alcohol misuse history, and admission bicarbonate level < 20 mmol/L

Alcohol-Positive Risk Score	Alcohol-Positive	*p*-value	Chi-square value
0	10/173 (5.8%)		
1	91/308 (29.6%)		
2	128/202 (63.4%)		
3	39/45 (86.7%)	< 0.0001	188.9

BAC-positive proportion was 36.9% (270/731; 95% CI: 33.5-40.5%). For the 270 BAC-positive patients, the mean BAC was 184.9 ± 101.0 mg/dL (range, 12-488 mg/dL), and the number of patients with a BAC ≥ 100 mg/dL was 205 (75.9%). BAC positivity was greater in patients with a smoking history (41.6% [151/363]) than in non-smokers (31.5% [117/365]; $P = 0.0061$; OR = 1.5). BAC positivity was greater in patients with an alcohol misuse history (87.4% [174/199]) than in those without (17.9% [95/530]; $P < 0.0001$; OR = 31.2).

Among 729 trauma activation patients aged 18-60 years (without or with alcohol misuse), the BAC-positive proportion was higher with a bicarbonate level < 20 mmol/L (49.0% [140/286]) than with a bicarbonate level ≥ 20 mmol/L (29.1% [129/443]; $P < 0.0001$; OR = 2.3). The alcohol-positive proportion progressively increased as the alcohol-positive risk score value increased and had an area under the receiver operating characteristic curve of 0.80 (**Table 3**; **Figure 1**). The BAC-positive proportion was higher with a BAC risk score of 2 or 3 (67.6% [167/247]) than with a BAC risk score of 0 or 1 (21.0% [101/481]; $P < 0.0001$; OR = 7.9). In 737 trauma activation patients aged 18-60 years, multivariate logistic regression analysis showed that BAC-positive patients had simultaneously increased proportions of alcohol misuse ($P < 0.0001$) and a bicarbonate level < 20 mmol/L ($P < 0.0001$) (r-square = 0.4550). The proportion of patients with a bicarbonate level < 20 mmol/L was higher among the those with an ISS ≥ 20 (59.2% [87/147]) than among those with an ISS < 20 (34.2% [202/591]; $P < 0.0001$; OR = 2.8). In

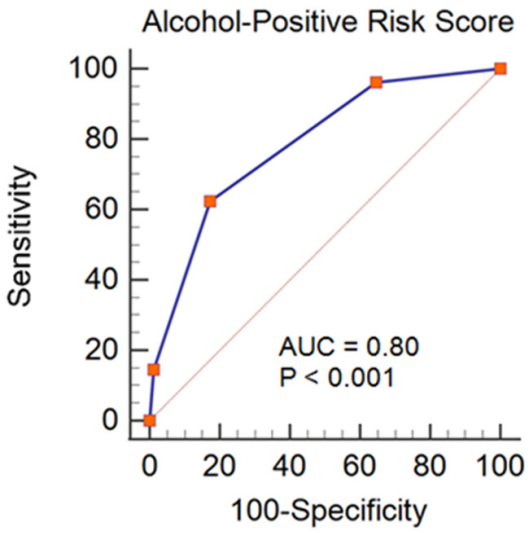

Figure 1. Alcohol-positive risk score. Note: AUC, area under the curve.

738 trauma activation patients aged 18-60 years, multivariate logistic regression analysis showed that a bicarbonate level < 20 mmol/L was simultaneously associated with the absence of alcohol misuse (P < 0.0001), BAC positivity (P < 0.0001), and ISS ≥ 20 (P < 0.0001).

Trauma activation patients aged 18-60 years audit: alcohol misuse associations

The proportion of those with alcohol misuse was greater in the BAC-positive patients (64.7% [174/269]) than in the BAC-negative patients (5.4% [25/460]; P < 0.0001; OR = 31.2). A BAC-positive result had an alcohol misuse positive predictive value of 64.7% and an alcohol misuse sensitivity of 87.4%. A BAC-negative result represented a negative predictive value of 94.6% for alcohol misuse. The relationship between a BAC-positive or -negative result relative to the presence or absence of alcohol misuse had a specificity of 82.1% and a test accuracy of 83.5%. The proportion of those with alcohol misuse was greater in the ≥ 40-year-old patients (37.2% [121/325]) than in the < 40-year-old patients (19.1% [79/413]; P < 0.0001; OR = 2.5).

In patients without or with alcohol misuse, the proportion of those with a bicarbonate level < 20 mmol/L was higher among BAC-positive patients than among BAC-negative patients (**Table 4**). In the subset of patients without alcohol misuse, the proportion of those with a bicarbonate level < 20 mmol/L was even higher among BAC-positive patients than among BAC-negative patients (**Table 4**). In the subset of patients with alcohol misuse, the proportion of those with a bicarbonate level < 20 mmol/L was similar among BAC-positive patients and BAC-negative patients (**Table 4**).

The proportion of those with a GCS 3-14 was higher among BAC-positive patients (42.6% [115/270]) than among BAC-negative patients (29.9% [138/461]; P = 0.0005; OR = 1.7). Among BAC-positive patents, those with alcohol misuse had less metabolic acidosis, higher BAC levels, and higher BAC ≥ 100 mg/dL with GCS ≥ 13 proportions than those without (**Table 5**). Among 269 BAC-positive patients, multivariate logistic regression analysis showed that patients with alcohol misuse simultaneously had higher proportions of a bicarbonate level ≥ 20 mmol/L (P < 0.0001) and BAC ≥ 100 mg/dL with GCS ≥ 13 (P < 0.0001) (r-square = 0.2279). For BAC-positive and BAC-negative patients, the proportion of those aged ≥ 40 years was higher with alcohol misuse (60.5% [121/200]) than without (37.9% [204/538]; P < 0.0001; OR = 2.5). In BAC-negative patients, the proportion of those aged ≥ 40 years was higher with alcohol misuse (68.0% [17/25]) than without (38.9% [169/435]; P = 0.0039; OR = 3.4).

The proportion of patients with alcohol misuse was higher with an alcohol misuse risk score of 3-5 (74.4% [142/191]) than with a risk score of 0-2 (10.4% [57/546]; P < 0.0001; OR = 24.9; area under the receiver operating characteristic curve = 0.89) (**Figure 2**). Multivariate logistic regression analysis of 737 trauma activation patients aged 18-60 years where all variables were able to be classified showed that alcohol misuse was simultaneously associated with a BAC-positive status (P < 0.0001), BAC ≥ 100 mg/dL with GCS ≥ 13 (P < 0.0001), age ≥ 40 years (P < 0.0001), and bicarbonate level ≥ 20 mmol/L in BAC-positive patients (P < 0.0001) (r-square = 0.5193).

Discussion

Main findings

The primary study finding was that younger trauma activation patients had an increased

Table 4. Comparisons of bicarbonate level < 20 mmol/L in BAC-negative and BAC-positive patients

	BAC-Negative BIC < 20	BAC-Positive BIC < 20	*p*-value	OR
All patients	31.7% (146/460)	52.0% (140/269)	< 0.0001	2.3
No alcohol misuse	31.4% (136/435)	73.7% (70/95)	< 0.0001	6.1
Alcohol misuse	40.4% (10/25)	40.2% (70/174)	1.0	1.0

Notes: BAC, blood alcohol concentration; BIC < 20, bicarbonate level < 20 mmol/L; OR, odds ratio.

Table 5. Comparisons of alcohol-positive patients without and with an alcohol misuse history

	No Misuse	Misuse	*p*-value	Cohen d	OR
Number of patients	95	174			
Bicarbonate level < 20 mmol/L	70 (73.7%)	70 (40.2%)	< 0.0001		4.2
BAC, mg/dL	116 ± 83	223 ± 89	< 0.0001	1.2	
GCS	13.0 ± 3.6	13.5 ± 3.1	0.3064		
BAC ≥ 100 mg/dL with GCS ≥ 13	37 (39.0%)	137 (78.7%)	< 0.0001		5.8

Notes: OR, odds ratio; BAC, blood alcohol concentration; GCS, Glasgow Coma Scale score.

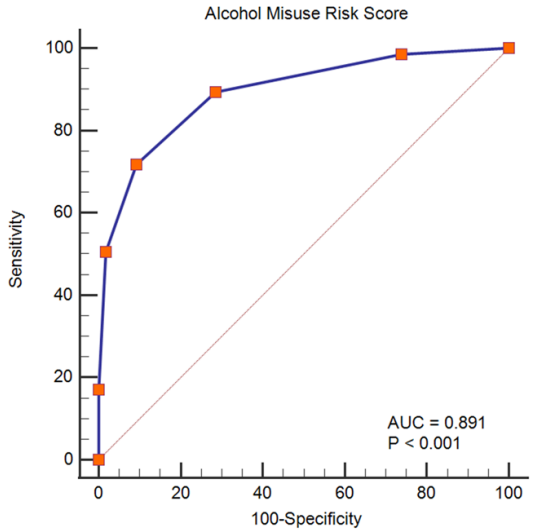

Figure 2. Alcohol misuse risk score. Note: AUC, area under the curve.

BAC-positive proportion compared to other patients, confirming the first study hypothesis. The BAC-positive proportion was nearly 40%. Other key younger trauma activation patient findings showed that BAC positivity was associated with smoking history, alcohol misuse history, and metabolic acidosis, validating the second study hypothesis. Another major younger trauma activation patient finding showed that an alcohol misuse history was associated with 1) a positive smoking history, 2) a positive blood alcohol test result, 3) age ≥ 40 years, 4) the absence of metabolic acidosis with a blood alcohol-positive finding, and 5) cognitive preservation despite intoxication, confirming the third study hypothesis. Additionally, patients with an increased ISS had a greater degree of metabolic acidosis. Based on these findings, we believe that patients who are BAC-positive or have a positive smoking or alcohol misuse history need to be readily identified so they can receive proper care.

Parent group: alcohol associations

The BAC testing proportion of 61% in all of the current study trauma center admissions (trauma activation patients and consult patients) was higher than the 34-44% proportions described in four other cohorts of trauma center admissions [9-11]. Therefore, BAC testing potentially provides a greater ability to determine factors that are associated with BAC-positive outcomes. BAC testing proportions were increased in patients with a GCS 3-14, ISS 21-75, age 18-60 years, male sex, penetrating trauma, and trauma activation. Because we have been unable to find similar relationships described in the literature, we are unable to corroborate these observations.

The overall BAC-positive proportion of 30% in all of the current study trauma center admissions is similar to the 32-39% proportions found in four other cohorts of trauma center admissions [9-11]. BAC-positive proportions in the current study were increased in patients with an ISS 21-75, age 18-60 years, and male

sex. Although eight other trauma investigations have shown that BAC-positive proportions were associated with an increased ISS [12, 15-18, 20, 23, 24], three other studies have demonstrated that BAC-positive proportions were associated with a decreased ISS [4, 19, 21]. While some other trauma researchers have also found associations between BAC-positive proportions in younger trauma patients [13, 14], other investigations have found BAC-positive associations in older patients [17, 22]. Similarly, findings in the literature are conflicting regarding the association of male patients with an increased BAC-positive status. One study showed that BAC-positive proportions were increased in men compared to women [14], whereas another investigation failed to find a BAC-positive increase in men [13]. Although risk conditions for a BAC-positive result are variable in the literature, the typical trauma cohort proportion is approximately 30%.

Trauma activation patients aged 18-60 years: variable classifications and comorbidities

Of 742 trauma activation patients aged 18-60 years patients, the EMR audit variables were classified according to data availability. Most of the supplementary EMR audit variables (alcohol misuse and smoking histories, and admission serum bicarbonate level < 20 mmol/L) were able to be categorized in nearly 100% of the patients. An alcohol misuse history was found in 27% and a smoking history in 50%. Multiple investigations have shown that smoking and alcohol misuse histories are associated with impediments in wellbeing and other adverse outcomes. Researchers have demonstrated that an alcohol misuse history is associated with increased anxiety disorders [27] and an increased negative affect [28]. Trauma investigators have also shown that an alcohol misuse history is associated with alcohol withdrawal syndrome [29] and trauma recidivism [30]. Other research has found that smokers have decreased wellbeing [31], an increased negative affect [32], and strong associations with numerous other adverse health effects [33]. Considering the common occurrences of these comorbidities and the adverse outcomes associated with these conditions, it is recommended that trauma patients should be routinely assessed for alcohol misuse and smoking. Potential strategies to identify patients with these conditions and interventions to mitigate the comorbidities are recommended.

Trauma activation patients aged 18-60 years: BAC-positive associations

Of 742 trauma activation patients aged 18-60 years, a BAC-positive status was able to be categorized in nearly 100%, and there was a BAC-positive proportion of 37%. Because BAC testing was nearly 100% and the 95% CI for the BAC-positive proportion was relatively narrow, the BAC-positive proportion should be considered highly precise. The younger trauma activation BAC-positive proportion in the current study is similar to that in the four other cohorts of trauma patients that demonstrated BAC-positive proportions of 32-39% [9-11]. Using combined random effect analyses, the overall BAC-positive proportion in these studies was 35.9% (95% CI: 32.3-39.7%) [9-11]. It is interesting to note that the proportion without BAC testing in these studies ranged from 56% to 66% [9-11].

BAC positivity was greater in patients with a smoking history than in the non-smokers, indicating that patients with a smoking history are more likely to present to the trauma center with a BAC-positive status. Other investigators have found that smoking is associated with hazardous alcohol consumption among trauma patients [6, 7] and non-trauma patients [8]. The current younger trauma activation investigation also found that BAC positivity was greater in patients with an alcohol misuse history than in those without, and it had an extremely large effect size. Other trauma investigations have also corroborated the observation that a BAC-positive status is associated with hazardous alcohol drinking or chronic alcoholism [1-3]. The current study results indicate that patients with alcohol misuse are substantially more likely to present to the trauma center with a BAC-positive result than those without alcohol misuse. It is important to note that a substantial proportion of patients with alcohol misuse were found in the current study to have a BAC-negative status, a finding noted by other investigators in 32-39% of patients with alcohol misuse [2, 3]. In trauma activation patients aged 18-60 years (without or with alcohol misuse), the proportion of those with a bicarbonate level

< 20 mmol/L was higher among BAC-positive patients than among BAC-negative patients. Other earlier trauma investigations have also found that BAC-positive patients have greater metabolic acidosis than BAC-negative patients [4, 5, 34].

Regarding the BAC-positive risk score, the BAC-positive proportion was substantially higher with a BAC-risk score of 2 or 3 than with a BAC-risk score of 0 or 1. In trauma activation patients aged 18-60 years, multivariate logistic regression analysis showed that BAC-positive patients had simultaneously increased proportions of alcohol misuse and a bicarbonate level < 20 mmol/L. These observations support the notion that smoking and alcohol misuse histories and metabolic acidosis are associated with a BAC-positive status.

The proportion of those with a bicarbonate level < 20 mmol/L was higher in patients with an ISS ≥ 20 than in those with an ISS < 20. This observation compellingly indicates that severe injury is associated with metabolic acidosis. Other trauma investigators have also demonstrated that metabolic acidosis is greater in patients with an increased ISS [34-37] or major injury [38] than in patients with a lower ISS or minor injury. Multivariate logistic regression analysis of trauma activation patients aged 18-60 years showed that a bicarbonate level < 20 mmol/L was simultaneously associated with the absence of alcohol misuse, BAC positivity, and ISS ≥ 20. Together, these findings support the notion that postinjury metabolic acidosis is related to a BAC-positive status. Because the Advanced Trauma Life Support manual advocates a routine arterial blood gas determination for patients meeting activation criteria, arterial bicarbonate and base deficit levels are routinely available for these patients [39]. A bicarbonate level < 20 mmol/L commonly indicates that a patient has a BAC-positive status.

Trauma activation patients aged 18-60 years: alcohol misuse associations

Of 742 trauma activation patients aged 18-60 years, smoking and alcohol misuse histories were available for nearly 100%. Smoking history proportions were higher in patients with alcohol misuse than in those without. Other investigators have also found that smoking is associated with hazardous alcohol consumption in studies of trauma patients [2, 6, 7] and a study of non-trauma patients [8]. These observations suggest that a history of smoking increases the likelihood that alcohol misuse is an underlying comorbidity.

In trauma activation patients aged 18-60 years (without or with alcohol misuse), the proportion of those with a bicarbonate level < 20 mmol/L was higher among BAC-positive patients than among BAC-negative patients. In the subset of patients without alcohol misuse, the proportion of those with a bicarbonate level < 20 mmol/L was also higher in BAC-positive patients than in BAC-negative patients, indicating that BAC-positive patients have a propensity for metabolic acidosis. However, the effect size (odds ratio) was substantially greater when compared to the total group without or with alcohol misuse. The propensity for metabolic acidosis was attenuated in patients with alcohol misuse; that is, there was no difference in the proportion of those with a bicarbonate level < 20 mmol/L between BAC-positive and BAC-negative patients. The aforementioned data indicate that BAC-positive patients with an alcohol misuse history do not have a propensity for metabolic acidosis. We have found no other research that has performed a similar investigation to either acknowledge or refute these findings.

The proportion of those with a GCS 3-14 was higher in BAC-positive patients than in BAC-negative patients. These data indicate that BAC-positive patients tend to have relative decrements in cognition. Among applicable studies of trauma patients, other investigators have found that alcohol intoxication adversely affects the admission GCS [40, 41]. A study that excluded head injuries demonstrated a reduction in the GCS for BAC-positive patients compared to BAC-negative patients [40]. When assessing BAC-positive patients, the current investigation found that patients with alcohol misuse had higher BAC levels and a GCS related cognitive preservation, when considering the degree of BAC intoxication level, than those without alcohol misuse. Several observations have shown that humans can develop central nervous system tolerance due to alcohol misuse. An alcohol expert has stipulated that individuals with a substantial elevation in the BAC

and whose cognition is relatively intact justifies the presumption that chronic alcohol misuse is likely [42]. Other published investigations provided objective evidence that trauma patients can have relative cognitive preservation despite marked elevations in the BAC [43, 44]. These findings indicate that humans can have a GCS that is relatively preserved despite a positive BAC; that is, the central nervous system can become physiologically accustomed to alcohol misuse.

Earlier in the manuscript, we showed that the alcohol misuse proportion is greater in BAC-positive patients, when compared to BAC-negative patients and has been corroborated by other investigators [1-3]. We also demonstrated that the alcohol misuse proportion is greater in patients aged ≥ 40 years. We have been unable to find any trauma patient literature that has demonstrated that alcohol misuse or hazardous drinking is associated with an increase in age. However, two trauma investigations have demonstrated that patients developing alcohol withdrawal syndrome were older than those who did not [45, 46]. Of potential relevance, two epidemiologic surveys have shown that older individuals have increased and excessive alcohol consumption and greater alcohol use disorder proportions, when compared to younger persons [47, 48].

Although the single marker, a BAC-positive result, had a substantial positive predictive value, sensitivity, and specificity for alcohol misuse, other conditions may signal the presence of an alcohol misuse history. A smoking history, the absence of metabolic acidosis with a BAC-positive result, age ≥ 40 years with a BAC-negative result, and cognitive preservation despite blood evidence of alcohol intoxication were found to be associated with alcohol misuse in univariate analyses and multivariate analyses (multivariate logistic regression and receiver operating characteristic curve statistical examinations). We principally recommend objective alcohol misuse screening by focusing on patients who are BAC-positive, even though a tangible number of patients with alcohol misuse will be BAC-negative. Investigators should also consider that 1) age ≥ 40 years with a BAC-negative finding, 2) a positive smoking history, 3) the presence of cognitive preservation, or 4) absence of a metabolic acidosis with a BAC-positive finding should heighten the probability that an alcohol misuse history is present.

Limitation

The principal limitation of the current study is the retrospective design; however, most of the data elements were prospectively documented in the EMR. This limitation particularly relates to the accuracy of the ascertainment of alcohol misuse and smoking histories.

Conclusions

It is highly probable that routine BAC testing in trauma activation patients aged 18-60 years will produce a positive result in nearly 40% of the tests. The probability of a BAC-positive result can be further increased or decreased when a composite assessment of alcohol misuse history, smoking history, and serum bicarbonate level < 20 mmol/L is considered. The current study notes that trauma activation patients aged 18-60 years with a BAC-positive result are likely to have a positive alcohol misuse use history. Other conditions increasing the probability of a positive alcohol misuse history are age ≥ 40 years, a positive smoking history, cognitive preservation with alcohol intoxication, and the absence of metabolic acidosis with a BAC-positive finding. The current retrospective study and literature indicate that BAC positivity, a smoking history, and an alcohol misuse history in trauma activation patients aged 18-60 years are interrelated. The literature also provides ample evidence that these conditions are associated with decreased psychological wellbeing, multiple adverse physical health outcomes, and trauma recidivism. We suggest that trauma center leadership should provide procedures to identify patients who are BAC-positive or have a positive smoking or alcohol misuse history. Then, patients with these conditions should be referred to care providers that can offer assistance and guidance for enhancing overall patient wellbeing. Future research should assess a similar study design; however, the data collection process should be prospective. Most importantly, the assessment and classification for determining alcohol misuse and smoking histories should be proactive, prospective, and with clear criteria.

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The current study was approved by the local institutional review board. The need for consent was waived because of the retrospective nature of the investigation.

Disclosure of conflict of interest

None.

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