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Original Contributions

ACUTE ALCOHOL INTOXICATION IN ADOLESCENTS: FREQUENCY OF RESPIRATORY DEPRESSION

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☐ **Abstract—Background: Adolescents and young adults are frequent users of alcohol. Younger patients may be more sensitive to the effects of alcohol than their adult counterparts, and toxicity has been known to occur at lower doses. Respiratory depression is a serious adverse effect of alcohol intoxication; however, current monitoring practices may not adequately detect respiratory depression. Objective: Our objective was to determine the frequency of hypoventilation as measured by capnography among adolescents with acute alcohol intoxication. Our secondary objective was to determine if an association exists between alcohol levels and incidence of hypoventilation. Methods: This was a prospective observational pilot study of patients 14–20 years of age with acute alcohol intoxication. Blood or breath alcohol measurements were obtained on arrival. Hourly measurements of vital signs including capnography were recorded. Results: Sixty-five subjects were analyzed. Mean alcohol level was 185 mg/dL. Twenty-eight percent of subjects had episodes of hypoventilation. Episodes occurred in similar proportions on arrival and during the first 5 h of measurements. There was no difference in alcohol levels between subjects who did and did not hypoventilate (185 mg/dL vs. 186 mg/dL; 95% confidence interval −29 to 25). Oxygen desaturations occurred in 14 subjects and were associated with hypoventilation (p = 0.015). Conclusions: Hypoventilation is common among adolescents who are acutely intoxicated with alcohol. It is independent of alcohol level and occurs at a steady rate during the first several hours of intoxication. Capnography should be considered as an additional monitoring device to detect these episodes and enhance patient safety.** © 2013 Elsevier Inc.

☐ **Keywords—hypoventilation; capnography; intoxication; alcohol; adolescents**

INTRODUCTION

Alcohol is a common drug of abuse among adolescents and young adults. It is estimated that at least 50% of adolescents 12–20 years old have imbibed alcohol during any 30-d period (1). This population also accounts for nearly 20% of all the alcohol consumed in the United States (US) (1). In 2008, the rate of Emergency Department visits related to alcohol alone was 220.7 per 100,000 children age 12–17 years and 596.3 per 100,000 young adults aged 18–20 years (2).

Alcohol is one of the most commonly abused drugs that can induce respiratory failure (3). Respiratory failure from central nervous system depression is a rare but serious consequence of alcohol intoxication. In adults, this has been known to occur in a dose-dependent fashion,

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as ethanol affects the respiratory center in the medulla oblongata (3). However, the effects of alcohol may be greater in children as compared with adults because children are unlikely to be tolerant to its effects (4).

Signs and symptoms of respiratory depression and impending respiratory failure due to alcohol intoxication can be subtle. Hypoventilation can occur due to changes in either respiratory rate or tidal volume. Bradypneic hypoventilation is due to a decline in respiratory rate and can only be detected by continuous monitoring either via plethysmography or capnography. Hypopneic hypoventilation, which is due to a decrease in tidal volume and concomitant increase in dead space ventilation, cannot be detected with standard monitoring devices and may be difficult to detect on clinical examination as well (5). Pulse oximetry is a continuous monitor of oxygenation, however, it does not adequately assess ventilation. Among patients with apnea, the most extreme form of hypoventilation, pulse oximetry may not begin to decline for several minutes—an unacceptable delay that will be lengthier in patients who are hypoventilating (6–8).

While the management of acutely intoxicated patients centers around monitoring and supportive care, it is unclear whether standard monitoring devices such as pulse oximetry are sufficiently sensitive in detecting respiratory depression. Capnography, or end-tidal carbon dioxide ($ETCO_2$) monitoring, is a continuous and objective way to monitor ventilation. This monitor can alert a provider within one breath to an airway or respiratory problem, thus demonstrating its superiority as a measure of ventilation (9). Many studies have shown the benefits of this device in the early detection of apnea and hypoventilation (10–12).

The primary objective of this study was to determine the frequency of hypoventilation as measured by capnography in adolescents and young adults with acute alcohol intoxication. Our secondary goal was to determine if an association existed between alcohol level and the incidence of hypoventilation. We hypothesized that hypoventilation would be detected more frequently by capnography compared with standard respiratory monitoring in adolescents and young adults who were acutely intoxicated. This would provide evidence for the value of continuous capnography monitoring in acutely intoxicated patients. We also hypothesized that subjects who developed hypoventilation would have higher alcohol levels than those who maintained normal ventilatory patterns.

METHODS

Between September 2007 and December 2010, a convenience sample of subjects with acute alcohol intoxication was enrolled in a prospective observational pilot study. The Human Investigations Committee approved this study with a waiver of consent. This study took place in the Pediatric Emergency Department of an urban tertiary care hospital. The Pediatric Emergency Department sees approximately 32,000 patients each year.

Subjects were eligible for enrollment if they were between the ages of 14 and 20 years of age and suspected of being acutely intoxicated with ethanol. Exclusion criteria included blood or breath alcohol levels <80 mg/dL, intubation prior to or upon arrival to the Emergency Department stay, traumatic injury prior to arrival, and any conditions that would affect $ETCO_2$ measurements, including evidence of major trauma, diabetic ketoacidosis, severe dehydration, or active lower airway disease.

Emergency Department staff collected basic demographic information including age, sex, and ethnicity. The presence or absence of vomiting was recorded. When possible, a serum alcohol panel and venous blood gas was obtained on arrival. The serum alcohol panel included measurements of ethanol, methanol, acetone, and isopropanol. Breath alcohol measurements (Alco-Meter III; Intoximeters Inc., St. Louis, MO) were taken on arrival and at regular intervals if the patient was awake and able to cooperate. These measurements were assumed to approximate serum levels when serum levels were not obtained. Additional toxicology screening tests were obtained at the discretion of the treating staff.

A Smart CapnoLine Plus (Oridion Capnography Inc., Needham, MA) nasal-oral cannula was placed in the patient's nose and overhanging the lip, then attached to a Nellcor NPB-70 portable monitor on loan from Nellcor Puritan Bennett LLC, doing business as Covidien (Boulder, CO). Cannulas were donated by Nellcor Puritan Bennett LLC. A pulse oximetry probe was also attached to the subject's finger to measure oxygen saturation and heart rate (Nellcor Puritan Bennett LLC, doing business as Covidien). Capnography is not routinely used for monitoring of intoxicated patients at this institution. For the purpose of this study, measurements of $ETCO_2$, respiratory rate, heart rate, and oxygen saturation were recorded every hour on a written data form while the patient was in the Emergency Department. Nursing staff or patient care associates typically performed this task. Data were not routinely disclosed to treating physicians, but were available upon request. Any additional significant clinical events, such as apnea or desaturations, were recorded. Similarly, staff interventions related to airway, oxygenation, or ventilation were recorded. These included administration of supplemental oxygenation, patient stimulation, repositioning, insertion of an oral or nasal airway, application of continuous positive airway pressure ventilation, bag-valve mask ventilation, and endotracheal intubation. Staff recording $ETCO_2$ measurements did not receive any additional training for the purposes of this study, however, all members of the

Pediatric Emergency Department receive mandatory orientation and competency-based training, which includes the use of equipment. As measurements were not routinely reported to the treating physicians, the majority of their clinical decisions were made independent of $ETCO_2$ values.

The primary outcome was frequency of hypoventilation as measured by capnography. This was defined as an $ETCO_2$ level either ≤30 mm Hg, indicative of hypopneic hypoventilation caused by a decrease in tidal volume, or an $ETCO_2$ level ≥50 mm Hg, indicative of bradypneic hypoventilation caused by a decrease in respiratory rate (5,9,10,13–15). Apnea was also considered hypoventilation and was defined as an $ETCO_2$ level of 0 mm Hg.

Primary Data Analysis

Based on reports of a 31.7% detection rate of respiratory acidosis via blood gas analysis in acutely intoxicated adults, we sought to enroll 60 patients in this study in order to detect a group of subjects with hypoventilation (16). To detect a linear correlation of $r = 0.4$ between alcohol levels and $ETCO_2$ measurements with a power of 0.8 and a significance level of 0.05 we would need 46 subjects in this study. Characteristics of enrolled subjects were summarized with descriptive statistics, including mean (minimum, maximum) and frequencies with percent. Categorical variables were compared between subjects with and without hypoventilation with Fisher's exact test or χ^2 statistic. Mean alcohol levels of patients with hypoventilation and those without were compared using a *t*-test and analyzed for linear correlations. Data were analyzed using PASW Statistics 18.0 (SPSS Inc., Chicago, IL).

RESULTS

Seventy-one subjects were enrolled and 65 subjects were included in the data analysis. Reasons for exclusion included lack of documentation of alcohol intoxication (n = 4) and alcohol level not indicative of intoxication (n = 2). No subjects removed the nasal-oral cannula because of discomfort or combativeness. Demographic information for the study subjects is presented in Table 1. There were a total of 283 recordings on the subject population, with a median of 4 recordings for each subject (range of 1–9). Eight recordings (0.03%) were missing $ETCO_2$ measurements.

Serum alcohol levels were obtained for 57 subjects (88%), and 40 subjects (62%) had breath alcohol measurements on arrival. Thirty-eight subjects had both of these measurements taken. There was excellent correlation between serum and breath alcohol levels on arrival (correlation coefficient 0.81; $p < 0.001$) when both were obtained simultaneously. If both values were present, the serum level was used in all analyses. Mean alcohol level of our subjects was 185 mg/dL (range 104–301 mg/dL). A venous blood gas was obtained on 47 subjects. Test results are presented in Table 2.

Table 1. Patient Characteristics (n = 65)

Characteristic	
Age (years), mean (range)	16.4 (14–19)
Sex, n (%)	
Male	40 (61.5)
Female	25 (38.5)
Race/ethnicity, n (%)	
Caucasian	42 (65)
African-American	8 (12)
Hispanic	12 (19)
Other	1 (2)
Presence of vomiting, n (%)	44 (68)

Hypoventilation as measured by capnography was found to occur in 28% of subjects. The majority of episodes (92%) were indicative of hypopneic hypoventilation with an $ETCO_2$ ≤30 mm Hg. There were two episodes of apnea and two episodes with $ETCO_2$ recordings ≥50 mm Hg. Twelve subjects had one episode, 5 subjects had two episodes, and 1 subject had three episodes of hypoventilation or apnea documented. No episodes were recorded after the 5th hour of monitoring; however, there were ≤10 subjects remaining at these time intervals. Frequency of hypoventilation over time is shown in Figure 1.

There was no difference in the mean alcohol levels of patients with (186 mg/dL; range 104–267 mg/dL) and without (185 mg/dL; range 107–301 mg/dL) episodes of hypoventilation (95% confidence interval of mean difference –29 to 25). Only six subjects (9%) exhibited respiratory rates <12 breaths/min (mean 10 breaths/min), three of which were on arrival. None of these subjects had evidence of hypoventilation by capnography during this study.

There were 34 patient interventions that occurred in 13 subjects (20% of total). These included administration of supplemental oxygen (n = 30), airway repositioning

Table 2. Results of Serum (n = 57) and Breath (n = 40) Alcohol Levels and Venous Blood Gas Measurements (n = 47) Taken on Arrival to the Emergency Department

Test	Mean (Range)
Alcohol level (mg/dL)	
Serum	190 (104–301)
Breath	144 (90–240)
Venous pH	7.33 (7.23–7.45)
Venous P_{CO_2} (mm Hg)	46 (18–62)
Glucose (mg/dL)	119 (52–280)

P_{CO_2} = partial pressure of carbon dioxide.

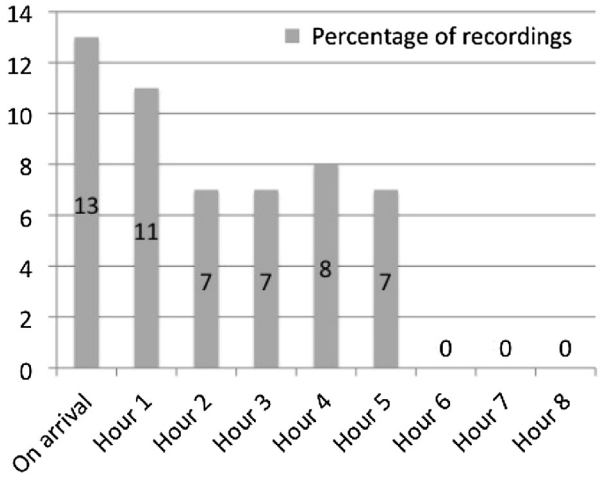

Figure 1. Percentage of end-tidal carbon dioxide recordings indicating hypoventilation or apnea per hour.

(n = 3), and verbal stimulation (n = 1). There were no significant differences in the age, initial alcohol level, presence of vomiting, pH, or partial pressure of carbon dioxide in mixed venous blood of patients with or without episodes of hypoventilation as measured by capnography in subjects with or without airway interventions (Table 3). No enrolled subjects received assisted ventilation during this study. Oxygen desaturations <95% occurred in 13 subjects (20%) and oxygen desaturations <90% occurred in 2 subjects (3%). Both subjects with oxygen desaturations <90% and 7 (54%) of the subjects with oxygen desaturations <95% experienced episodes of hypoventilation. Oxygen desaturations were significantly associated with episodes of hypoventilation (relative risk = 3.7; 95% confidence interval 1.5–9.2). Pulse oximetry remained >95% in 11 subjects (61%) who exhibited evidence of hypoventilation via capnography.

DISCUSSION

This study demonstrated a high frequency of hypoventilation in adolescents and young adults who were acutely intoxicated with alcohol. These episodes were difficult to predict, occurring in similar proportions over the first several hours of intoxication. Furthermore, there was no correlation between initial alcohol level and risk of hypoventilation.

The number of children with acute intoxication has been on the rise (17–19). Approximately 25% of US high school students report binge drinking, having five or more drinks in a row, in the last month (20,21). Serum alcohol levels as low as 100 mg/dL can have a significant impact on adolescents and alcohol-naïve adults and can manifest as severe toxicity (4,22). In this study, subjects with levels as low as 104 mg/dL had episodes of hypoventilation.

Respiratory depression is one of the leading causes of death from acute intoxication (23,24). It can occur from the effect of alcohol on respiratory centers as well as from its sedating effects that lead to decreased levels of consciousness. A recent study revealed that among hospitalized youth who were acutely intoxicated, the primary reason for admission was reduced consciousness in 94% of patients (25). This reduced consciousness lasted up to 16 h and 11% of subjects required intensive care (25). Similar to our findings, in which there was a lack of correlation between hypoventilation and alcohol level, Bouthoorn et al. found no correlation between state of consciousness and blood alcohol levels (18).

The ability to monitor the respiratory status of patients who are intoxicated is critical. Adequate oxygen saturation as measured by pulse oximetry does not imply that ventilation is appropriate. Capnography is a noninvasive way to monitor the ventilatory status of spontaneously breathing patients. It can detect respiratory depression from both falling tidal volumes, as $ETCO_2$ measurements fall below 30 mm Hg, and declining respiratory rates, as $ETCO_2$ rises above 50 mm Hg. When respiratory depression develops secondary to central nervous system depressants such as alcohol, tidal volume initially falls, leading to low $ETCO_2$ levels, as a larger proportion of dead space ventilation occurs (3). This offers an explanation as to why the majority of hypoventilation

Table 3. Patient Characteristics and Test Measurements Based on Presence or Absence of Hypoventilation and Airway Interventions

	Hypoventilation		Airway Intervention	
	+ (n = 18)	− (n = 47)	+ (n = 13)	− (n = 52)
Initial alcohol level (mg/dL), mean (SD)	186 (49.1)	185 (47.4)	184 (49.8)	185 (48.4)
Age (year), mean (SD)	16.3 (1.0)	16.4 (1.2)	16.7 (0.8)	16.3 (1.2)
+Vomiting (%)	71	68	85	65
pH, mean (SD)	7.36 (.03)	7.32* (.05)	7.34 (.05)	7.33 (.05)
$PVco_2$ (mm Hg), mean (SD)	45 (8.4)	47 (9.8)	47 (8.6)	46 (9.6)

$PVco_2$ = partial pressure of carbon dioxide in mixed venous blood; SD = standard deviation.
* $p < 0.05$.

episodes in this study were secondary to hypopnea instead of bradypnea. Standard respiratory plethysmography and clinical examination are not likely to detect these events because they measure respiratory rate but not tidal volume.

In children with central nervous system and respiratory depression secondary to sedatives, capnography is able to detect hypoventilation and apnea prior to clinical examination or changes in pulse oximetry (10,26–30). Pulse oximetry and physical examination are both subject to inaccuracies, delays, and inter-observer variability (31). When a patient is not adequately oxygenating, ventilating, or is apneic, pulse oximetry might not show a change for 2–3 min (6,7). Unlike pulse oximetry, there is no delay between changes in the patient's ventilation and that seen by capnography.

Ethanol has been shown to impair the ventilatory response to simultaneously increasing hypercapnia and hypoxia mediated by peripheral chemoreceptors up to 95 min after ethanol ingestion (32,33). Respiratory acidosis is the most frequent metabolic derangement found in acutely intoxicated adults, seen in 37% of subjects (16). Although venous sampling was performed in this study, a much higher proportion of respiratory acidosis was found in our population of adolescents; however, this was not associated with a greater risk of hypoventilation. Respiratory stability must be ensured while serum alcohol levels slowly return to nontoxic levels.

Low $ETCO_2$ levels have also been shown to correlate with metabolic acidosis. It has previously been shown that adults who are acutely intoxicated suffering from minor trauma have a higher prevalence of metabolic acidosis than do nonintoxicated trauma victims (34). The level of acidosis was not found to be dose-dependent (34). However, low $ETCO_2$ levels in the setting of metabolic acidosis are related to a relative increase in ventilation, as excess CO_2 is expired. In our subjects, where a low $ETCO_2$ level was noted, there was no concomitant rise in their respiratory rates to account for this change. Similarly, there were few documented cases of metabolic acidosis via venous blood gases and cases with a low pH were not more likely to have low $ETCO_2$ levels than those with a normal pH.

Supportive care and careful monitoring are key aspects in the management of intoxicated adolescents. Hypoventilation can be corrected with simple patient maneuvers, such as verbal or physical stimulation. We demonstrated here that subjects who hypoventilated were 3.7 times more likely to develop hypoxemia than those adolescents with normal ventilation. When detection and intervention can occur expeditiously, the development of hypoxemia and further respiratory depression can be prevented (11). However, persistent hypoventilation and hypoxemia may require ventilatory support either with noninvasive positive-airway pressure devices or via short-term mechanical ventilation.

Limitations

Our study has several limitations. Serum alcohol levels were not obtained on all of our patients. However, it has been shown that breath alcohol levels have excellent correlation with blood alcohol levels (35–38). This held true in our sample. While hypoventilation was found in a significant proportion of our patients, our treating physicians did not deem aggressive airway support clinically necessary based on other patient parameters. However, this was a small observational pilot study, and capnography measurements were not routinely incorporated into clinical decision making. Similarly, monitoring was not continuous in nature for this study, and it was not possible to record continuous data with this device, so the frequency and duration of these episodes might be underestimated. The need for more aggressive ventilatory management would require the evaluation of a larger sample of patients who are being monitored continuously after staff training in the interpretation of capnography.

CONCLUSIONS

Hypoventilation, as measured by capnography, occurs frequently in adolescents and young adults who are acutely intoxicated with alcohol, is independent of initial alcohol level and is a risk factor for hypoxemia. These episodes do not steadily decrease over time, but occur in similar proportions throughout the first several hours of intoxication. Capnography should be considered as an additional monitoring device for these patients until their alcohol levels have returned to normal.

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ARTICLE SUMMARY

1. Why is this topic important?

Alcohol intoxication is common among adolescents and diligent monitoring is a key aspect of their care. Respiratory depression is a serious consequence of alcohol intoxication, which may be undiagnosed by current methods.

2. What does this study attempt to show?

Capnography is a more sensitive monitoring device for the detection of hypoventilation in acutely intoxicated adolescents.

3. What are the key findings?

Respiratory depression as measured by capnography is frequent among adolescents with acute alcohol intoxication. Respiratory depression was not associated with changes in respiratory rate and was independent of alcohol concentration and time.

4. How is patient care impacted?

Capnography should be considered when monitoring these patients. Monitoring of intoxicated youth should remain vigilant during the entire Emergency Department course as hypoventilation may occur at any time.