#1

ORIGINAL CONTRIBUTION

The Relationship of Blood Alcohol Concentration to Impairment Severity in Spinal Cord Injury

Martin Forchheimer, MPP[1]; Rebecca M. Cunningham, MD[2]; David R. Gater, Jr, MD, PhD[3]; Ronald F. Maio, DO, MS[4]

[1]Model Spinal Cord Injury Care System, Department of Physical Medicine and Rehabilitation, University of Michigan, Ann Arbor, Michigan; [2]Department of Emergency Medicine, University of Michigan, Ann Arbor, Michigan; [3]Model Spinal Cord Injury Care System, Department of Physical Medicine and Rehabilitation, University of Michigan, VA Ann Arbor Healthcare System, Ann Arbor, Michigan; [4]Department of Emergency Medicine, University of Michigan, Ann Arbor, Michigan

Received February 1, 2005; accepted May 13, 2005

Abstract

Objective: To investigate the relationship between blood alcohol concentration (BAC) and severity of neurological impairment.

Design: Retrospective cross-sectional study.

Participants: Subjects with traumatic spinal cord injury (SCI; N = 119) with dates of injury between 1991 and 2000 who received their acute treatment at a midwestern Model SCI Care System and for whom information regarding BAC was available.

Analysis: Main outcome measure: severity of neurological impairment. Data were analyzed using χ^2 tests and analysis of variance (ANOVA).

Results: A significant association was observed between impairment severity and BAC.

Conclusions: The study suggests that alcohol consumption is associated with severity of SCI. A more rigorous study controlling for trauma attributes is necessary to confirm these results and appraise whether alcohol has a potentiating effect on impairment. If borne out, the study's findings may lead to alterations in emergency room procedures and to changes in public health and education efforts resulting from a reframing of the issue of safe consumption of alcohol.

J Spinal Cord Med. 2005;28:303–307

Key Words: Spinal cord injuries; Blood alcohol concentration; Impairment severity; Tetraplegia; Paraplegia

INTRODUCTION

In contrast to the improvements in automotive safety features, emergency treatment procedures, and education efforts directed toward injury prevention that have occurred in recent years, there have been no apparent reductions in the incidence of spinal cord injury (SCI) or the tolls that SCI exacts, both on individual and societal levels. Approximately 11,000 new cases of SCI occur each year and the average costs for health care and living expenses during the first year after SCI range from $185,000 to $627,000, depending on the level of injury (1). Chronic SCI is associated with a variety of health problems, including hypertension (2), cardiovascular disease, and diabetes mellitus (3). Furthermore, people with SCI often face economic hardship, as is evidenced by their high rates of chronic unemployment (4).

Alcohol consumption is known to be a risk factor for serious accidents that can result in SCI and other severe trauma. Numerous reasons for this have been proposed. Alcohol slows the rate of visual scanning (5) and reduces the ability to attend to random stimuli, such as are experienced while driving (6). Additionally, alcohol consumption is associated with increased risk-taking behavior (7). Men, who incur the majority of SCI, have lower perceptions of the risks of drinking and driving than do women (8).

Although the legal, public health, and educational communities have stressed the dangers associated with

Please address correspondence to Martin Forchheimer, MPP, University of Michigan, Model Spinal Cord Injury Care System, Department of Physical Medicine and Rehabilitation, North Ingalls Building Room NI2A09, 300 N Ingalls, Ann Arbor, MI 48109-0419; phone: 734.763.0971; fax: 734.936.5492 (e-mail: forchm@umich.edu).

Grant support provided by the National Institute of Disability and Rehabilitation Research, grant #H133N000009.

inappropriate use of alcohol, particularly among people operating motor vehicles, the impact of these efforts has not been optimal. According to a 1999 study, 0.001% of all kilometers are driven by people with a blood alcohol concentration (BAC) of equal or greater than 0.10%; this increases to 14% on weekend nights (9).

It is accepted that alcohol use is associated with increased incidence of traumatic injuries, including SCI, with enhanced risks occurring among people engaged in violence and sports (9,10) in addition to vehicular use. In addition to increasing incidence of trauma, however, there are indications that alcohol consumption may also lead to worse outcomes among those who incur trauma. Laboratory studies have suggested that alcohol has a potentiating and detrimental effect, and that even relatively small doses may significantly increase susceptibility for increased trauma severity. In animal studies, survival rates and severity of neurological impairment have been linked to alcohol (11,12). Other studies have observed that alcohol exposure has an effect at the cellular level, reducing cell membrane integrity (13).

Unlike the laboratory evidence, clinical evidence has been inconsistent. Two studies conducted with general trauma patients in the 1990s found that having a positive BAC, (+) BAC, was not associated with worse outcomes, controlling for factors such as seatbelt use and chronic alcohol abuse (14,15). A study of clinical outcomes among people with SCI that contrasted Functional Independence Measure scores for people with (+) BAC and (–) BAC also found no differences (16). Other studies came to conflicting conclusions: subjects with a (+) BAC experience greater blood loss, require more operative procedures (17), and incur more severe traumatic brain injuries (18). A survey of men with SCI found that, controlled for a number of factors, tetraplegia was more prevalent among those who had consumed alcohol at the time of injury (19). A study that controlled for crash characteristics found that motor vehicle crash victims with (+) BAC had significantly higher injury severity scores than did those with (–) BAC (20). As suggested by some laboratory research, this study found alcohol consumption to be associated with elevated injury severity scores even for low levels of (+) BAC.

A proper understanding of these issues has important implications for society in terms of education, policy, and treatment. Our legal system is focused on prevention of driving while grossly intoxicated; having consumed alcohol sufficient to impair judgment and response time. Similarly, our education efforts focus on ameliorating the problem of drunk driving. Although successfully eliminating clinically impaired drivers from the roads would have a significant positive impact on public safety, these combined public health efforts may have the erroneous and unintended effect of suggesting that driving after lower levels of alcohol consumption is essentially safe. Additionally, if potentiation does occur, public health messages need to explain that all vehicle passengers are at risk for injuries of increased severity, and thus, although it will prevent accidents, having a designated driver is only a partial solution.

The current study explores the relationship between BAC and trauma severity among people with SCI, assessed in terms of level and degree of neurological impairment. The hypothesis follows from current understandings based on laboratory research and clinical studies looking at more general injury severity measures. The specific hypothesis guiding this research is that, when injured, individuals with a (+) BAC have more severe neurological impairments than do those with a (–) BAC.

METHODS

Participants

The study sample is comprised of 119 persons who received inpatient acute care for new, traumatic SCI from a Model SCI Care System located in the Midwestern United States during the period between 1991 and 2000. Either they must have received emergency services there or, if transferred from another institution, records concerning their initial BAC must have been available for them to qualify for study inclusion. Persons younger than 16 years were excluded from the sample pool as were those with concurrent traumatic brain injuries, the latter because American Spinal Injury Association (ASIA) examinations are less reliable in this population (21).

Measures

Blood alcohol content was assessed based on blood work done shortly after admission to the Emergency Department. Subjects were classified with (+) BAC if their BACs were greater than zero. In 5 cases, although laboratory values could not be obtained, determination was made based on clinical notes included in subjects' medical charts that explicitly stated that they had a (+) BAC. These subjects were excluded from those secondary analyses for which exact BAC values were required.

Data on etiology were obtained from the center's local database, which shares a common structure with that of the National Spinal Cord Injury Statistical Center database. A record review found that within this sample, all etiologies fell into 1 of 3 global categories: vehicular, violence, or sports. Because mechanism of injury rather than type of activity was of interest, sports etiologies were reclassified as either vehicular or falls, depending on which type of impact the specific sporting activity best reflected. For example, whereas diving is classified as a sports etiology, mechanistically, it is appropriately classified as a fall. Conversely, auto racing is most appropriately classified as a vehicular etiology.

Impairment severity was classified using a 3-level system that combines completeness and level of injury. This classification system is based on the International Standards for Neurological Classification of Spinal Cord Injury developed by ASIA and the International Medical Society of Paraplegia (22). The 3 neurological groupings

are: ASIA grade D, regardless of level of injury (ASIA D); paraplegia, ASIA grades A, B, or C (Para ABC); and tetraplegia, ASIA grades A, B, or C (Tetra ABC). Neurological assessment was based on subjects' initial assessments within 24 hours after injury, on entry to the institution's acute care facilities.

Statistical Analysis

Preliminary analyses involved exploring differences between the sample members with (+) BAC and (−) BAC in terms of their demographic attributes. Subsequently, to address the primary hypothesis that individuals with a (+) BAC would have more severe impairments, subjects with (+) BAC and (−) BAC were contrasted in terms of their neurological status, using χ^2 tests. As an additional analysis, analysis of variance (ANOVA) was performed to assess the relationship between impairment severity and BAC among those subjects with (+) BAC.

RESULTS

Of the 119 subjects in the study, 50 (42%) had a (+) BAC at the time of their injury. Among those with a (+) BAC, the mean BAC was 0.15 with a standard deviation of 0.06. Seventy-five percent of these persons had a BAC greater than 0.11, and for 25%, BACs exceeded 0.18. Among the total sample, 34% had BACs greater than 0.08, the maximal level at which people over the age of 21 can legally operate a motor vehicle; among those with (+) BAC, 87% had BACs greater than 0.08.

The breakdown of subjects by severity of neurological impairment is: ASIA D, 13%; Para ABC, 40%; and Tetra ABC, 47%. Males were more likely to have a (+) BAC than were females, as were nonmarried subjects. Although overall, level of education was associated with alcohol consumption at time of injury, this relationship was not a simple one, with the highest rates of (+) BAC being found among those having completed high school; those with lower or higher levels of education had similarly lower rates. A depiction of the study subjects is shown in Table 1.

Analysis of the relationship between BAC status and the severity of neurological impairment on admission to acute care indicates that, as hypothesized, those with a (+) BAC did have more severe impairments ($\chi^2 = 6.91$; $P < 0.05$). Among those with a (+) BAC, 60% had Tetra ABC impairments, compared with 38% of those with a (−) BAC. In contrast, 6% of individuals with a (+) BAC had ASIA D impairments, compared with 17% of those with (−) BAC. These results are shown in Table 2.

Analysis within the (+) BAC subsample of the relationship between BAC and impairment severity demonstrated no relationship. Analysis of variance found nominal differences among the 3 impairment groups in terms of BAC ($F = 0.32$; $P = 0.73$).

DISCUSSION

This study is unique in looking at BAC in relationship to SCI. Its findings provide support for our hypothesis. People incurring SCI with a (+) BAC tended to have more severe impairments than did those with (−) BAC, as defined by their neurological status on admission to acute care. Additionally, our data suggest that the relationship observed between alcohol consumption and severity of impairment is not a function of level of consumption.

There are 2 different explanations for the observed relationship between BAC and severity of neurological impairment. First, the trauma characteristics for those with (+) BAC and (−) BAC may differ. Second, alcohol

Table 1. Sample Characteristics

	(−) BAC	(+) BAC	Total
Gender*			
Male	50.5%	49.5%	83.2%
Female	95.0%	5.0%	16.8%
Marital status**			
Married	76.0%	24.0%	57.6%
Not married	44.1%	55.9%	42.4%
Education***			
< High school	76.7%	23.3%	28.0%
High school	50.0%	50.0%	52.3%
> High school	76.2%	23.8%	19.7%
Etiology			
Vehicular	58.1%	41.9%	62.2%
Violence	58.3%	41.7%	10.1%
Falls	57.6%	42.4%	27.7%
Age, y (SD)	36.4 (13.4)	35.7 (11.1)	36.1 (12.4)
Length of hospitalization, d (SD)	73.2 (47.8)	69.5 (44.3)	71.7 (46.1)

*$P < 0.0005$; **$P < 0.001$; ***$P < 0.05$.

Table 2. Cross-Tabulation of Alcohol Consumption and Level of Neurological Impairment on Hospital Admission

Neurological Group	(−) BAC	(+) BAC	Total
ASIA impairment scale grade D	17.4%	6.0%	12.6%
Paraplegia, ASIA grades A, B, or C	44.9%	34.0%	40.3%
Tetraplegia, ASIA grades A, B, or C	37.7%	60.0%	47.1%
Total	58.2%	42.0%	...

N = 119; $\chi^2 = 6.91$; $df = 2$; $P = 0.032$.

may have a potentiating effect on severity. This study was not able to address the first of these explanations, although there have been a number of studies that suggest that there are systematic differences in the accident conditions for alcohol-involved traumas, for instance, people with a (+) BAC who are injured in vehicular accidents are less likely to wear seat belts (23). The study's findings do provide support for previous laboratory and clinical research that advocated the potentiation theory (14–16,18–21), suggesting that this is observed in SCI. The analysis of differences in impairment severity among the subsample with a (+) BAC is concurrent with the proposition that this potentiating effect commences at low BAC (13,22). These 2 explanations, differences in trauma attributes and potentiation, are not in conflict; both may be correct.

The authors recognize several study limitations, not the least of which is the inability to control for trauma severity. Few subjects had a low BAC, and, thus, although the conclusions are likely to be valid in the moderate and high BAC range, it is unclear whether it is appropriate to extrapolate them to low levels, for which there were relatively few observations. The delay between trauma and BAC assessment may have led some subjects with initially low BAC levels to be misclassified as having a (−) BAC. This may have underestimated the magnitude of the relationship between BAC and impairment. Finally, the small sample size prohibited the conduct of multivariate analyses.

CONCLUSION

Although numerous studies have been conducted that have explored the role of alcohol as a risk factor, this study is novel in its appraisal of the impact of alcohol consumption on injury severity among people with SCI. It indicates that people using alcohol tend to have more severe SCI and that this may be independent of amount of consumption. Future, prospective studies that control for trauma severity can formally address the issue of whether alcohol has a potentiating effect on impairment severity in SCI, and, if it does, at what BAC this commences. If, as this study suggests, there is a potentiating effect with a relatively low onset, there are significant implications for how we as a society conceptualize "safe drinking," and as a result, this may warrant changes to our public health and education efforts. It would be important to teach that just as driving under the influence of alcohol is dangerous, so too is "riding while under the influence." Similarly, the risks inherent in driving with a subclinical BAC would need to be more plainly stressed. These findings could also have important implications for modification to emergency protocols, perhaps leading to changes in patient assessments and triage practices based on whether a patient has a (+) BAC.

REFERENCES

1. National Spinal Cord Injury Statistical Center, August 2004. Facts and Figures. Available at: http://www.spinalcord.uab.edu/show.asp?durki=21446. Accessed May 17, 2005.
2. Yekutiel M, Brooks ME, Ohry A, Yarom J, Carel R. The prevalence of hypertension, ischaemic heart disease and diabetes in traumatic spinal cord injured patients and amputees. *Paraplegia.* 1989;27(1):58–62.
3. Kocina P. Body composition of spinal cord injured adults. *Sports Med.* 1997;23(1):48–60.
4. Hess DW, Meade MA, Forchheimer M, Tate DG. Psychological well-being and intensity of employment in individuals with a spinal cord injury. *Top Spinal Cord Inj Rehabil.* 2004;9(4)1–10.
5. Moser A, Heide W, Kompf D. The effect of oral ethanol consumption on eye movements in healthy volunteers. *J Neurol.* 1998;24(5):542–550.
6. Newman D, Speake DJ, Armstrong PJ, Tiplady B. Effects of ethanol on control of attention. *Hum Psychopharmacol.* 1997;12(3):235–241.
7. Brismar B, Bergman B. The significance of alcohol for violence and accidents. *Alcohol Clin Exp Res.* 1998;22(7):299s–306s.
8. Mundt JC, Ross LE, Harrington HL. A modeling analysis of young drivers' judgments of accident risk due to alcohol-use and other driving conditions. *J Stud Alcohol.* 1992;53(3):239–248.
9. Miller TR, Spicer RS, Levy DT. How intoxicated are drivers in the United States? Estimating the extent, risks and costs per kilometer of driving by blood alcohol level. *Accid Anal Prev.* 1999;31(5):515–523.
10. Chalmers DJ, Morrison L. Epidemiology of non-submersion injuries in aquatic sporting and recreational activities. *Sports Med.* 2003;33(10):745–770.
11. Shapira Y, Lam AM, Paez A, Artru AA, Laohaprasit V, Donato T. The influence of acute and chronic alcohol treatment on brain edema, cerebral infarct volume and neurological outcome following experimental head trauma in rats. *J Neurosurg Anesthesiol.* 1997;9(2):118–127.
12. Halt PS, Swanson RA, Faden AI. Alcohol exacerbates behavioral and neurochemical effects of rat spinal cord trauma. *Arch Neurol.* 1992;49:1178–1184.
13. Shih CL, Chi SI, Chiu TH, Lin TN. Ethanol effects on nitric oxide production in cerebral pial cultures. *Alcohol Clin Exp Res.* 2001;25(4):612–618.
14. Andersen JA, McLellan BA, Pagliarello G, Nelson WR. The relative influence of alcohol and seatbelt usage on severity

of injury from motor vehicle crashes. *J Trauma.* 1990;30(4): 415–417.
15. Jurkovich GJ, Rivara FP, Gurney JG, Fligner C, Ries R, Mueller BA. The effect of acute alcohol intoxication and chronic alcohol abuse on outcome from trauma. *JAMA.* 1993;270(1):51–56.
16. McKinley WO, Kolakowsky SA, Kreutzer JS. Substance abuse, violence, and outcome after traumatic spinal cord injury. *Am J Phys Med Rehabil.* 1999;78(4):306–312.
17. Sommers MS, Schackmann J, Wallace M, Von Rotz N, Willhite JM. Circulatory response of young adult trauma victims with alcohol intoxication. *J Subst Abuse.* 1994;6(4): 449–456.
18. Cunningham RM, Maio RF, Hill EF, Zink BJ. The effects of alcohol on head injury in the motor vehicle crash victim. *Alcohol Alcohol.* 2002;37(3):236–240.
19. Garrison A, Clifford K, Gleason SF, Tun CG, Brown R, Garshick E. Alcohol use associated with cervical spinal cord injury. *J Spinal Cord Med.* 2004;27(2):111–115.
20. Waller PF, Hill EM, Maio RF, Blow FC. Alcohol effects on motor vehicle crash injury. *Alcohol Clin Exp Res.* 2003;27(4): 695–703.
21. Lemke DM. Defining assessment parameters in dual injuries: spinal cord injury and traumatic brain injury. *SCI Nurs.* 1995;12(2):40–47.
22. American Spinal Injury Association (ASIA). *International Standards for Neurological Classification of Spinal Cord Injury.* 6th ed. Chicago, IL: ASIA; 2000.
23. Li L, Kim K, Nitz L. Predictors of safety belt use among crash-involved drivers and front seat passengers: adjusting for over-reporting. *Accid Anal Prev.* N199931(6):631–638.