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Life-threatening alcohol-related traffic crashes in adverse weather: a double-matched case–control analysis from Canada

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ABSTRACT

Importance Drunk driving is a major cause of death in North America, yet physicians rarely counsel patients on the risks of drinking and driving.

Objective To test whether the risks of a life-threatening alcohol-related traffic crash were further accentuated by adverse weather.

Design Double matched case–control analysis of hospitalised patients.

Setting Canada's largest trauma centre between 1 January 1995 and 1 January 2015.

Participants Patients hospitalised due to a life-threatening alcohol-related traffic crash.

Exposure Relative risk of a crash associated with adverse weather estimated by evaluating the weather at the place and time of the crash (cases) compared with the weather at the same place and time a week earlier and a week later (controls).

Results A total of 2088 patients were included, of whom the majority were drivers injured at night. Adverse weather prevailed among 312 alcohol-related crashes and was significantly more frequent compared with control circumstances. The relative risk of a life-threatening alcohol-related traffic crash was 19% higher during adverse weather compared with normal weather (95% CI: 5 to 35, p=0.006). The absolute increase in risk amounted to 43 additional crashes, extended to diverse groups of patients, applied during night-time and daytime, contributed to about 793 additional patient-days in hospital and was distinct from the risks for drivers who were negative for alcohol.

Conclusions Adverse weather was associated with an increased risk of a life-threatening alcohol-related traffic crash. An awareness of this risk might inform warnings to patients about traffic safety and counselling alternatives to drinking and driving.

Strengths and limitations of this study

- Comprehensive analysis of patients hospitalised for life-threatening alcohol-related traffic crashes over two decades at Canada's largest trauma centre.
- Innovative case-only self-matched study design examining the crash location with the same time and place exactly 1 week earlier and 1 week later.
- Study limitations are innevitable because a randomised trial of drunk driving is not ethical, driving patterns vary in different regions and many important details were not available including traffic volumes, speeds, spacing and enforcement.
- Further limitations include uncertainties around the exact mechanisms of the increased risks and why the risks are distinct to drunk drivers.
- Additional limitations include a lack of data on other hazards and on the effectiveness of clinician counselling for mitigating traffic risks.

INTRODUCTION

Alcohol-related traffic crashes cause substantial mortality and morbidity, accounting for ten thousand deaths annually in North America and contributing to one-third of total traffic fatalities.[1] Alcohol-related traffic fatality rates are higher in North America than many other countries that have greater alcohol consumption per-capita.[2–4] In addition, life-threatening alcohol-related traffic crashes in Canada and the USA result in over 300 000 patients hospitalised for brain trauma, spinal cord injuries, orthopaedic fractures or other non-fatal complications (leading to $43 billion in societal costs annually).[5 6] These patterns indicate that current public education, regulation and enforcement are insufficient for preventing drunk driving.[7 8]

Motorists who drive drunk do so many times before attracting the attention of a healthcare provider.[9 10] Epidemiological studies and statistical models estimate the average drunk driver needs to travel more than a million miles to cause one crash fatality.[11–13] This seemingly innocuous pattern tends to build a false sense of security from prior personal experiences; specifically, a mistaken belief that the individual can drive without incident if the road situation remains the same and free of other hazards.[14] This faulty reasoning is particularly beguiling because alcohol is a necessary but not a sufficient factor in triggering an alcohol-related traffic crash and because drunk drivers lack insights on how even minor hazards might precipitate a crash.[15]

One particularly common objective hazard is adverse weather that can create an extended disturbance for all who share the road.[16] Adverse weather reduces visibility, decreases vehicle traction, creates visual glare, obscures reflective road markings and changes the patterns of vehicle cross traffic.[17 18] Naturally, everyday driving entails an endless configuration of potential additional hazards that vary for each person and are easily forgotten after an uneventful trip.[19] The unrecognised effect of these hazards, however, might create a fundamental mechanism explaining the complex link between drunk driving and traffic crashes. In this study, we test the association of adverse weather with the risk of a life-threatening alcohol-related traffic crash.

METHODS

Patient selection

We identified consecutive adults admitted to Canada's largest trauma centre, a tertiary care hospital that treats patients from crashes in the country's largest province.[20–22] For a comprehensive analysis, we included all patients hospitalised for a crash (hereafter termed a life-threatening crash) including drivers, passengers or pedestrians since multiple individuals can be injured in traffic.[23 24] We focused on those who tested positive for alcohol based on history, examination, assay or police report. Unclassified or atypical road incidents were excluded (eg, skateboard misadventures). Enrolment spanned from 1 January 1995 to 1 January 2015 yielding a complete sample for the two most recent available decades.[25]

Clinical characteristics

We obtained clinical characteristics for patients based on hospital records using a standardised method validated in past research.[26] Information on the time, date and place of the crash was collected from paramedic reports if available and hospital records otherwise.[27] Information on patient age, sex, comorbidity, vital signs (after paramedic resuscitation), Injury Severity Score and Glasgow Coma Scale was based on chart review.[28 29] Of note, alcohol testing was routine in hospital trauma protocols and did not require consent. Further clinical details included surgical procedures, intensive care unit admission, total length of stay and hospital mortality.[30] The available records lacked information on driver education, past infractions, addiction history, license suspensions, impact velocity, vehicle condition, distance travelled or intended destinations.

Crash setting

Data on crash locations spanned a wide diverse geographic area (1 million km^2), were extracted in differing formats (street intersection, geographic coordinates, postal code) and were subsequently transformed to exact geocodes for the crash site.[31 32] Patients with missing or inexact crash locations were retained for analysis, denoted explicitly and subjected to sensitivity analysis. Geographic proximity to the trauma unit was estimated by Euclidean (straight-line) distance for those with known crash locations and by the median distance for those with missing or inexact crash locations. Crash time was recorded to the nearest hour to match the precision of standardised archived weather information.[33]

Adverse weather

The official Canada Climate Data and Information Archive provided weather data indexed to date and hour, as validated in past research.[34] We focused on adverse conditions defined in the archive as rain, fog, drizzle, showers, snow, storms, freezing rain or freezing drizzle.[35 36] All other conditions were defined as normal and included clear, mainly clear, mostly cloudy and cloudy. Daytime was crudely distinguished from night-time using simple thresholds of 07:00 and 19:00 hours. [37] We selected the weather station closest to the crash for patients with exact crash locations and the most central airport weather station for patients with inexact crash locations so no case was excluded (cases with inexact locations also subjected to sensitivity analysis).

Control comparisons

We identified two control days for each crash defined by the circumstances a week earlier and a week later (when presumably no other traffic crash was present).[38] A crash at midnight on 14 July 2011, for example, was compared with the same place at midnight on 7 July 2011 and 21 July 2011. This case-only design controlled for seasonal, daily and hourly trends; required no matching on individual patient characteristics; avoided ecological bias; and minimised multiple potential confounders including age, sex, genetics, personality, habits, education and road configuration.[39] The prevailing weather at the same time and place for crashes and control days was extracted in a blinded manner (no knowledge of outcome), with rare cases of missing weather data substituted by the immediately preceding hour so all comparisons were complete.

Statistical analysis

Our prespecified primary analysis involved a matched evaluation of individual cases comparing the prevalence of adverse weather on the crash day to the prevalence of adverse weather on the control days at the same time and place.[40] The relative risk of a crash associated with adverse weather was calculated using conditional logistic regression (accounting for 1:2 matching).[41 42] Stratified analyses were conducted to further account for individual characteristics. Secondary analyses repeated the calculations for drivers who were negative for alcohol to check if the risks associated with adverse weather were distinct to drinking and driving. All estimates were calculated using exact 95% CIs and considered each patient a separate case.

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Table 1 Patient characteristics

	Alcohol-positive Patients (n=2088)	Alcohol-negative Patients (n=8111)
Age (years)		
<25	538 (26)	1698 (21)
25–44	968 (46)	2716 (33)
45–64	453 (22)	2244 (28)
≥65	129 (6)	1453 (18)
Male	1707 (82)	5191 (64)
Medical comorbidity*	732 (35)	2684 (33)
Protective device active†	772 (37)	4201 (52)
Abnormal vital signs‡	482 (23)	1465 (18)
Decreased Glasgow Coma Score§	549 (26)	1475 (18)
Position		
Driver	1362 (65)	5249 (65)
Passenger	294 (14)	1047 (13)
Pedestrian	432 (21)	1815 (22)
Night-time¶	1395 (67)	2599 (32)
Spring and summer	1184 (57)	4639 (57)
Weekend	944 (45)	2433 (30)
First decade**	1214 (58)	3642 (45)
Exact crash location	1341 (64)	4774 (59)
Injury Severity Score		
<15	644 (31)	2598 (32)
15–24	565 (27)	2318 (29)
25–34	441 (21)	1694 (21)
≥35	438 (21)	1501 (19)

Primary analysis based on alcohol-positive patients (alcohol-negative shown for context).
*Hypertension or diabetes most commonly.
†Denotes seatbelts or helmets.
‡Denotes hypotension (blood pressure <100), tachycardia (heart rate >120) or tachypnea (respiratory rate >25).
§Denotes decreased consciousness (value <15).
¶Night-time is 19:00 to 07:00 hours, daytime is 07:00 to 19:00 hours.
**First decade is 1995 to 2004, second decade is 2005 to 2014.

Table 2 Acute medical care

	Alcohol-positive Patients (n=2088)	Alcohol-negative Patients (n=8111)
Summary measure		
Ambulance transportation*	2030 (97)	7739 (95)
Blood transfusion†	693 (33)	2549 (31)
Surgery performed‡	1162 (56)	4406 (54)
Critical care admission§	1251 (60)	4105 (51)
Length of stay >7 days¶	1194 (57)	4630 (57)
Patient death**	174 (8)	815 (10)

*Manner of arrival to hospital.
†Denotes one or more units of red blood cell transfusions.
‡Defined as operating room procedure.
§Includes medical or surgical intensive care unit.
¶Interval in hospital from admission to discharge.
**Case fatality during index hospitalisation.

RESULTS

A total of 10 199 patients were injured because of a life-threatening traffic crash during the study, of whom 2088 (20%) tested positive for alcohol (exact concentrations unavailable for analysis). The majority of the alcohol-related crashes involved patients as drivers, most occurred at night and less than half used a seatbelt (table 1). Alcohol-related crashes were distributed throughout the year, although counts were marginally higher in the spring and summer months. As expected, alcohol-related crashes were more common on weekends than weekdays and slightly more numerous during the first decade than the second decade of the study. An exact crash location was identified for the majority of patients regardless of whether the crash was alcohol-related.

The average patient in an alcohol-related crash was a middle-aged adult with no medical comorbidity. Men were disproportionately involved, as were those younger than age 65 years and those who had not been wearing a seatbelt. Patients in an alcohol-related crash were no less seriously injured as measured by the distribution of abnormal vital signs, decreased Glasgow Coma Scale scores or Injury Severity Scale scores compared with patients who were negative for alcohol. Almost all patients were transported to hospital by ambulance (table 2). One-third of the patients required blood transfusions, over half required surgery and over half required a critical care admission. Ultimately, 174 patients died following an alcohol-related crash.

Overall, 312 of the 2088 (15%) alcohol-related crashes were characterised by adverse weather conditions. In contrast, 537 of the 4176 (13%) control days were characterised by adverse weather conditions at the same time and place (figure 1). The difference in prevailing weather equalled a 19% increased risk of a life-threatening alcohol-related traffic crash associated with adverse weather compared with normal weather (95% CI: 5 to 35, p=0.006). The absolute difference amounted to 43 additional life-threatening alcohol-related traffic crashes associated with adverse weather (one-in-seven of those observed). In contrast, drivers who were negative for alcohol showed no increased risk of a life-threatening traffic crash associated with adverse weather (estimate = −1%, 95% CI: −11% to +8%, p=0.704).

The increased risk of a life-threatening alcohol-related traffic crash extended to diverse patient groups (figure 2). Drivers tended to predominate, yet the relative increase in risk associated with adverse weather also applied to

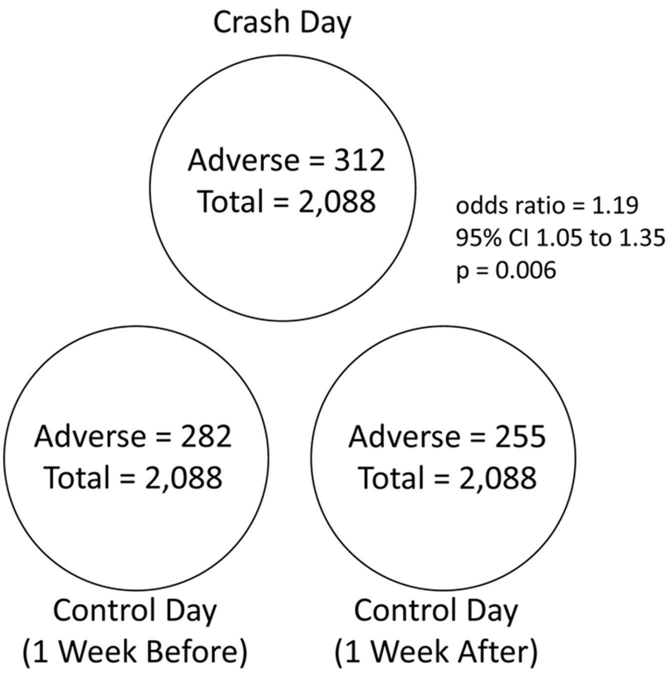

Figure 1 Venn diagram of summary data. Summary data based on 2088 alcohol-related life-threatening traffic crashes. Circles show counts of days with adverse weather at the time of the crash, at the control day 1 week before the crash and at the control day 1 week after the crash. For example, top circle indicates 312 of 2088 total crashes had adverse weather at the time and place of the crash. Main findings show disproportionate number of crash days with adverse weather compared with control days with adverse weather. OR indicates the relative frequency of adverse weather associated with a crash and is mathematically equal to the relative frequency of a crash associated with adverse weather (by the standard logic of case–control designs). OR calculated using exact methods that also account for matching in all triplets.

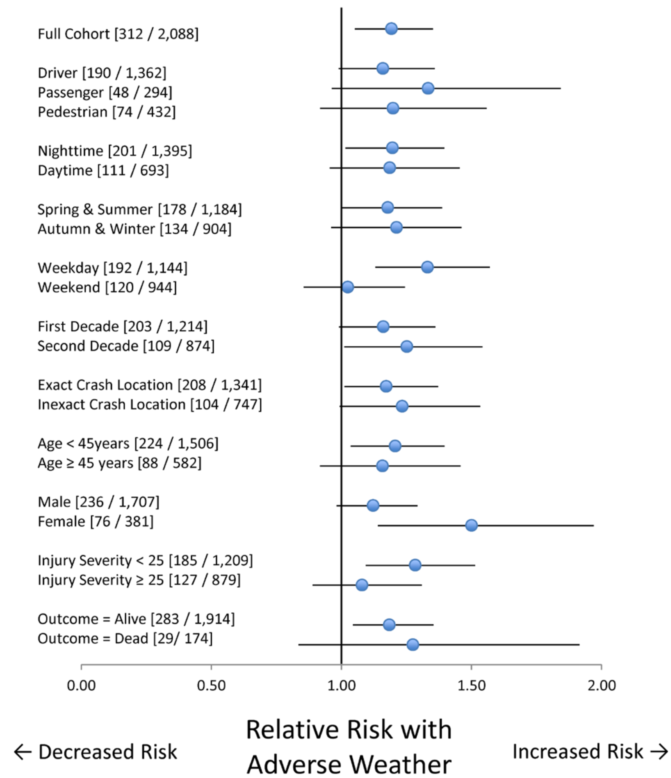

Figure 2 Analyses in patient subgroups. Forest plot showing relative risk of a life-threatening alcohol-related traffic crash associated with adverse weather. X-axis denotes relative risk with the null association indicated by a vertical line. Y-axis shows different analyses with full cohort analysis positioned at the top. Numbers enclosed by square brackets provide count of crashes with adverse weather and total sample size of cases in each subgroup. Solid circles indicate relative risk estimates and horizontal lines indicate 95% CIs. Values to the right of 1.00 denote increased risk and CIs that exclude 1.00 are statistically significant (p<0.05). Findings show increased risk across diverse subgroups with all CIs overlapping the primary analysis.

pedestrians and passengers (low counts). Similarly, nighttime crashes were more numerous than daytime crashes, yet the increased relative risk associated with adverse weather applied regardless of the time of day. Analyses stratified by season, weekday, decade, crash location, age, sex, Injury Severity Scale scores and mortality all showed increased relative risks of an alcohol-related traffic crash associated with adverse weather and wide 95% CIs. No analysis showed the opposite pattern, no pairwise interaction term was statistically significant and all point-estimates overlapped the primary analysis.

The increased risk of a life-threatening alcohol-related traffic crash associated with adverse weather resulted in substantial inpatient hospital care. The mean length of hospital stay was similar for patients injured in adverse weather conditions compared with patients injured in normal weather conditions (figure 3). In total, the absolute increase in risk associated with adverse weather accounted for about 793 additional patient-days in hospital (online supplementary appendix). Similarly, the absolute increase in risk associated with adverse weather accounted for 52 additional surgical operations and 255 additional patient-days in critical care (online supplementary appendix). The net economic consequences were equivalent to approximately $1 million in additional economic costs (online supplementary appendix).

DISCUSSION

We studied about 2000 patients injured in a life-threatening alcohol-related traffic crash over twenty years in Canada. We found that adverse weather was prevalent in many cases, accounted for a further 19% increased relative risk and might explain one-in-seven life-threatening alcohol-related crashes. The increased risk associated with adverse weather extended to diverse patient groups, applied during night-time and daytime, and accounted for hundreds of additional patient-days in hospital. An increased relative risk of this magnitude is twice as large as driving without an air bag and an absolute risk of this magnitude is particularly important due to the high baseline risk of a traffic crash for all drunk drivers.[43–46]

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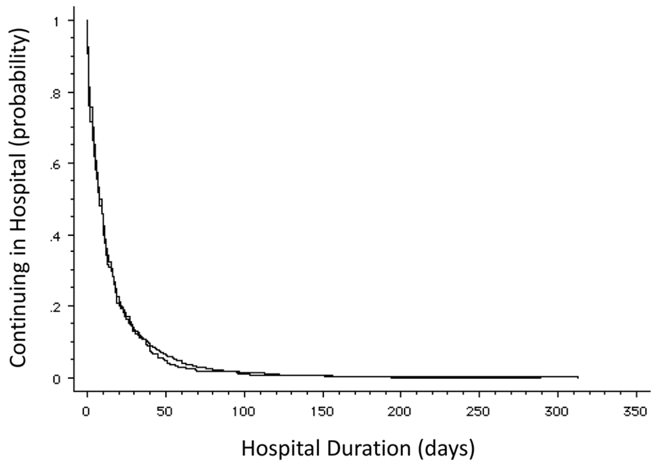

Figure 3 Length of hospital stay. Kaplan-Meier graph of time spent in hospital by patients following 2088 alcohol-related life-threatening traffic crashes. X-axis shows time from admission in days. Y-axis shows proportion not yet discharged from hospital. Superimposed crossing lines denote crashes occurring in adverse weather and crashes occurring in normal weather conditions. Main findings show similar mean, median and distribution of length of hospital stay for both groups.

Several limitations of our findings merit emphasis. The study is not a randomised trial because the weather is impossible to control and drunk driving cannot be assigned in an ethical manner. Trauma centre medical assessments often underestimate the presence of alcohol, yet this imprecision tends to slant primary and stratified analyses towards the null.[47] Alcohol studies cannot be blinded easily so unconscious biases in clinicians might distort the assessment of outcome data.[48] Our analysis also lacks data on traffic volumes, distances, speeds, spacing and finer weather details at exact crash sites.[49] Finally, the background degree of traffic enforcement is uncertain, fluctuates on an hourly basis and stays confidential to avoid subterfuge.[50 51]

Additional limitations relate to our study setting and justify replication in future research on other patients with life-threatening alcohol-related traffic crashes. The data reflect one large region that may not match drinking and driving patterns elsewhere.[52] Canada is also notorious for long cold dark nights that are conducive to alcohol consumption and an impediment to roadside traffic police.[53 54] Different regions have different traffic patterns and also vary in the age for legal drinking (19 years in most of Canada, 21 years in the USA).[55] Finally, we examined only one hazard that was objective and widespread yet daily traffic provides a large array of additional hazards that could precipitate a life-threatening alcohol-related crash.[56–58]

Alcohol causes traffic crashes because of impaired judgement, decreased attention, reduced alertness and many other factors that limit the ability to compensate for hazards.[59] A further subtle mechanism is how alcohol lowers visual acuity when moving. Laboratory experiments indicate, for example, that three drinks of alcohol cause a one-line loss on a Snellen eye chart test due to faulty visual tracking and reduced dynamic visual acuity.[60] Acute alcohol ingestion also causes decreased contrast sensitivity, sluggish glare adaption and impaired risk perception that is unnoticed when stationary.[61 62 63] The net effect is that eyesight deficits may be irrelevant when seated indoors (static vision), critical when driving in adverse weather (high-speed optical flow) and part of the false sense of security associated with drinking and driving.[64 65]

Our study suggests adverse weather is directly relevant for alcohol-related crashes yet does not identify all the other hazards accentuating the traffic risks. Worsened surface glare, wheel traction and light backscatter may compromise how nearby traffic compensates for an impaired driver.[66] External sensors or other assistive vehicle technologies can malfunction when wet.[67] Traffic police may also dislike adverse weather and reduce enforcement in the rain.[68 69] Together, these factors can help explain why adverse weather could be distinctly dangerous to drunk drivers; specifically, a crude OR of 25 associated with drunk driving might increase to a theoretical OR of 30 when driving in the rain (25×1.19). The net result could contribute to hundreds of patients requiring acute hospitalisation in North America each year (online supplementary appendix).[70]

An increased risk of a life-threatening alcohol-related crash associated with adverse weather also means that police enforcement alone is not an easy solution against drunk driving.[71 72] Traditional enforcement commonly includes sobriety checkpoints, mass media campaigns, encouraging seatbelts and random roadside alcohol breath testing.[73 74] These interventions, of course, are effective and merit continuation.[75] In daily practice, however, the inconvenience of police enforcement (especially in adverse weather) helps explain the high ongoing rates of drunk driving in many countries.[76 77] Clinicians wishing to save their patients from becoming more traffic injury statistics, therefore, might consider additional interventions beyond police enforcement.[78]

Drunk driving is a life-threatening behaviour, yet little data are available to guide clinicians for prevention.[79] Current clinical efforts mostly include treating alcohol misuse or reporting unfit drivers to licensing authorities.[80 81] Drunk driving, however, also stems from a patient's dismissal of health hazards that seem innocuous due to misleading past experiences. Clinicians intending to save patients from traffic injuries, therefore, might also counsel how crash risks vary substantially from one trip to the next due to adverse weather or other external hazards.[82] Such counselling could mention a pre-planned taxi or ride-sharing option since both inebriation and uneventful past experiences can impair judgement.[83] Although not prescribed by a physician, this study suggests that alcohol is a drug that endangers patients and justifies tactful medical attention.

Patient involvement statement

Patients were not involved directly in the design, conduct or reporting of this research. We are grateful for all patients, families and clinicians involved in trauma care. We remain committed to disseminating study results to patients and the broad community.

Possible tweet

Adverse weather is associated with an increased risk of an alcohol-related traffic crash.

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Contributors The lead author (DAR) wrote the first draft. Both authors (DAR, FM) contributed to study design, manuscript preparation, data analysis, results interpretation, critical revisions and final decision to submit. The lead author (DAR) had full access to all the data in the study, takes responsibility for the integrity of the data and is accountable for the accuracy of the analysis.

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Provenance and peer review Not commissioned; externally peer reviewed.

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