Motor vehicle crash fatalaties and undercompensated care associated with legalization of marijuana

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BACKGROUND:	Half of the US states have legalized medical cannabis (marijuana), some allow recreational use. The economic and public health effects of these policies are still being evaluated. We hypothesized that cannabis legalization was associated with an increase in the proportion of motor vehicle crash fatalities involving cannabis-positive drivers, and that cannabis use is associated with high-risk behavior and poor insurance status.
METHODS:	Hawaii legalized cannabis in 2000. Fatality Analysis Reporting System data were analyzed before (1993–2000) and after (2001–2015) legalization. The presence of cannabis (THC), methamphetamine, and alcohol in fatally injured drivers was compared. Data from the state's highest level trauma center were reviewed for THC status from 1997 to 2013. State Trauma Registry data from 2011 to 2015 were reviewed to evaluate association between cannabis, helmet/seatbelt use, and payor mix.
RESULTS:	THC positivity among driver fatalities increased since legalization, with a threefold increase from 1993–2000 to 2001–2015. Methamphetamine, which has remained illegal, and alcohol positivity were not significantly different before versus after 2000. THC-positive fatalities were younger, and more likely, single-vehicle accidents, nighttime crashes, and speeding. They were less likely to have used a seatbelt or helmet. THC positivity among all injured patients tested at our highest level trauma center increased from 11% before to 20% after legalization. From 2011 to 2015, THC-positive patients were significantly less likely to wear a seatbelt or helmet (33% vs 56%). They were twice as likely to have Medicaid insurance (28% vs 14%).
CONCLUSION:	Since the legalization of cannabis, THC positivity among MVC fatalities has tripled statewide, and THC positivity among patients presenting to the highest level trauma center has doubled. THC-positive patients are less likely to use protective devices and more likely to rely on publically funded medical insurance. These findings have implications nationally and underscore the need for further research and policy development to address the public health effects and the costs of cannabis-related trauma. (*J Trauma Acute Care Surg.* 2018;85: 566–571. Copyright © 2018 Wolters Kluwer Health, Inc. All rights reserved.)
LEVEL OF EVIDENCE:	Prognostic, level III.
KEY WORDS:	Marijuana; medical marijuana; cannabis; motor vehicle crash; Fatality Analysis Reporting System.

Over half of US states have legalized medical cannabis (marijuana), and a growing number (nine in 2018) have legalized it for recreational use.[1] However, the public health effects and economic impact of these policies are still being evaluated. A 2017 report from the National Academy of Sciences, Engineering and Medicine endorsed the therapeutic effects of cannabis and corroborated an earlier report stating there was insufficient evidence that cannabis use increased all-cause mortality.[1,2] However, a number of studies have suggested a correlation between cannabis use and a leading cause of death: motor vehicle crashes (MVC).

A recent meta-analysis concluded that driving under the influence of cannabis (DUIC) is associated with 20% to 30% higher odds of a motor vehicle crash.[3] The odds ratio was estimated to be even higher (>2) for fatal collisions, especially within 2 hours of using cannabis.[4,5] Colorado witnessed a 48% increase in cannabis-related traffic fatalities coincident with the commercialization of marijuana.[6] Despite this, overall traffic fatalities in states with legal cannabis are lower than those without, and the adoption of medical cannabis laws were temporally associated with immediate reductions in traffic fatalities in those aged 15 to 44 years.[7]

Proponents of legalized cannabis postulate a positive economic impact from savings to the criminal justice system due to elimination of the black market, reduced criminal prosecution, and conservation of law enforcement resources.[8] Selling cannabis can be lucrative: Colorado added US $115 million to its coffers from marijuana taxes in 2015.[6] It is unclear whether savings and revenue generation exceed the costs of regulation and public health expenses.

Following the leads of California, Alaska, Oregon, Washington, and Maine, Hawaii legalized the medical use of cannabis in 2000, becoming the first state to do so, through legislation.[9] The wider impact of this legislation on health care, particularly the trauma system, has not been completely evaluated. We hypothesized that cannabis legalization in the state has been associated with an increase in the proportion of motor vehicle crash fatalities involving cannabis-positive drivers. We further postulate that cannabis use is associated with high-risk behavior and poor insurance status.

Submitted: August 23, 2017, Revised: March 22, 2018, Accepted: May 8, 2018, Published online: May 21, 2018.

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DOI: 10.1097/TA.0000000000001983

METHODS

Fatalities

Fatality Analysis Reporting System (FARS) data for Hawaii were analyzed for periods before (1993–2000) and after (2001–2015) legalization. The presence of cannabinoids (THC), methamphetamine, and alcohol in fatally injured motor vehicle drivers (including motorcyclists) were compared. These characterizations were made using the DRUG_RES and ALC_RES fields, respectively. THC was indicated by DRUG_RES values of 600 through 695, and methamphetamine by code 417. Any ALC_RES level greather than 0 was considered alcohol positive. Testing of fatalities for alcohol was performed on blood samples at the medical examiners' office by gas chromatography. Urine toxicology results from the referring trauma centers were used to detect other substances (method below). If urine toxicology results from the referring center were not available, fatalities were screened at the medical examiners' office by Syva Rapid Test 10 (Siemens Healthcare, Norwood, MA) with threshold of detection for 11-nor-delta9-tetrahydrocannabinol-9-carboxylic acid (THC-OOH) of 0.1mg/ml. Fatalities with toxicology screens positive for illegal substances (excluding THC alone) had confirmatory testing with blood samples (NMS Labs, Willow Grove, PA) with threshold detection for THC of 0.5 ng/mL. The proportion of drug- and alcohol-positive drivers was determined in two ways, with and without the inclusion of untested drivers in the denominator.

A subset of Hawaii FARS data for recent years (2011–2015) were used to examine the association between cannabis positivity, methamphetamine and alcohol use, and crash demographics.

State Registry

Through 2010, there was one designated trauma center in the state, which has remained the highest level center. An additional three Level III centers were designated in 2011, and two in 2012. State Trauma Registry data were reviewed for THC status of trauma patients presenting to the highest level center from 1997 to 2013. Statewide data from 2011 to 2015 were used to evaluate association between cannabis use and risky behaviors (use of seatbelt restraint or helmet), as well as payor mix. At the state's trauma centers, presence of THC-COOH was determined by Enzyme Multiplied Immunoassay Test on urine, with a threshold of 50 ng/mL.

All statistical analyses were conducted with JMP software, version 5. Differences between groups were assessed using *t*-tests for continuous variables and χ^2 tests for categorical variables. The level of statistical significance was P less than 0.05.

RESULTS

FARS Data

A total of 1,578 motor vehicle drivers were killed in traffic crashes in Hawaii over the 23-year study period, with a generally decreasing trend in the annual number since 2006 (Table 1). Sixty-five percent of the decedents were drivers of automobiles, with drivers of motorcycles and mopeds comprising the remaining 35%. The proportion of the latter increased significantly over time, reaching 50% in the 2011 to 2015 period.

TABLE 1. Demographic and Toxicologic Descriptions of Drivers Killed in Traffic Crashes in Hawaii, 1993 to 2015 (n = 361 for 2001–2005, n = 374 for 2006–2010, n = 283 for 2011–2015; Total N = 1578)

	1993–2000	2001–2015	*P*
No. drivers	560	1018	
Vehicle type			
Car/truck	71% (400)	62% (627)	
Motorcycle/moped	29% (160)	38% (391)	<0.001
Age (mean ± SD)	37 ± 17	39 ± 17	0.030
Male sex	80% (448)	84% (855)	0.047
Positive for cannabis (THC), total*	6% (31)	15% (151)	<0.001
Positive for THC, tested**	6% (31)	16% (151)	<0.001
Positive for methamphetamine, total*	5% (27)	7% (74)	0.12
Positive for methamphetamine, tested**	5% (27)	8% (74)	0.047
Positive for alcohol, total*	47% (263)	46% (470)	0.84
Positive for alcohol, tested†	49% (263)	50% (470)	0.69

* Includes all fatally injured drivers.
**106 drivers were not tested for THC and methamphetamine.
†74 drivers were not tested for alcohol.

THC positivity among fatally injured drivers increased nearly threefold, from 5.5% in the 1993 to 2000 period to 16.3% in the 2011 to 2015 period (Fig. 1). This difference persists whether or not untested drivers are included. In contrast, the presence of methamphetamine, which has remained illegal, was not statistically different between the 1993 to 2000 (4.8%) and 2001 to 2015 (7.3%) periods when all drivers are included. There was a slight, significant increase in methamphetamine positivity rates when untested drivers are excluded. Alcohol positivity rates demonstrated no statistically significant change (Table 1).

THC-positive drivers were significantly younger than THC-negative drivers in recent years (Table 2). Although methamphetamine use was comparable between the two groups, alcohol use was 63% higher among the THC-positive drivers. THC-positive drivers were also more likely to have died in a night time crash and to have been speeding. The use of protective devices (seat belts for automobile occupants and helmets for motorcycle and moped drivers) was significantly lower among THC-positive drivers compared with those who tested negative.

State Registry Data

The rate of THC positivity among all injured patients tested at our highest-level trauma center increased from 11% before to 20% after legalization (Fig. 2). From 2011 to 2015, THC-positive patients were significantly less likely to have been wearing a seatbelt or helmet (33% vs 56%, Table 3). They were also twice as likely to have Medicaid insurance (28% vs 14%).

DISCUSSION

Over 8% of the US population older than 12 years are regular users of cannabis. Young adults (ages, 18–25 years) comprise approximately 20% of users,[10] correlating with the significantly lower mean age of THC-positive driver fatalities. The trend toward legalization and commercialization of cannabis has been

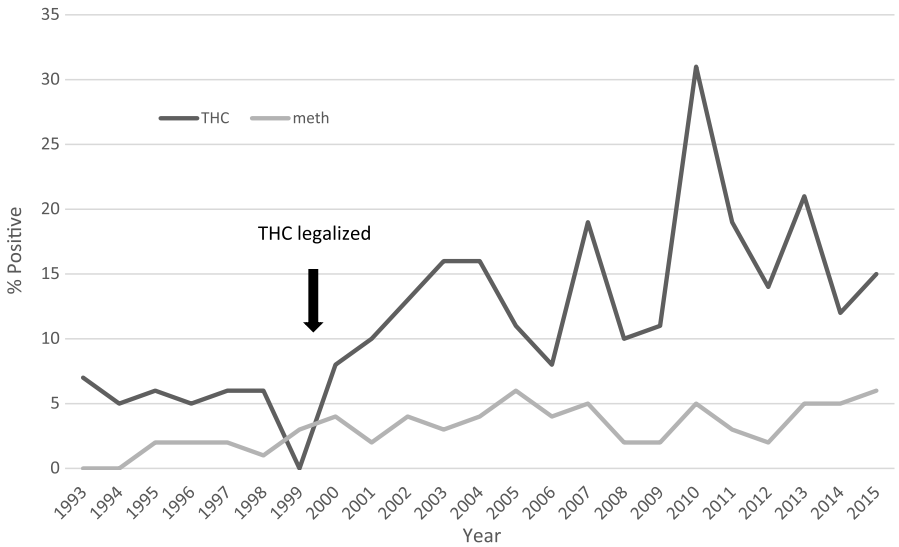

Figure 1. Annual percentage of fatally injured drivers testing positive for cannabis (THC) or methamphetamine (Meth) in Hawaii, 1993 to 2015.

fueled by reports of its medicinal use and a perception of its safety, due to inability to produce a fatal overdose.[11,12] Users are willing to drive under the effect of cannabis due to the perception that it is a "soft" illicit drug.[5]

The neurocognitive effects of cannabis are still being elucidated. There is evidence suggesting that long-term regular cannabis users have impaired retention, learning, and retrieval of information.[13] Experimental studies evaluating dose-response impairment of driving with cannabis have suffered from inconsistencies due to study design, cannabis dose, the sophistication of the equipment, and the specificity of the task. More recent simulator-based research has shown an increase in reaction time, lane position variability (weaving), and inability to maintain a constant headway while following another car.[14] Furthermore, cannabis users were observed to have increased risk taking behavior.[15] Conversely, an analysis of 414 MVC patients by Lowenstein and Koziol-McLain[16] did not demonstrate a causal relationship between DUIC and crash responsibility. However, they noted that users of nonalcohol drugs (including cannabis) were more likely to be unhelmeted or unrestrained. Legislation regarding DUIC is complex, prosecution remains relatively rare, and recidivism is high.[14,17]

Overall, MVC fatalities in Hawaii are 26% lower when compared with the rest of the United States, with reductions in motor vehicle occupants offset by higher mortality in motorcyclists.[18] Santaella-Tenorio et al[7] analyzed FARS data from 1985 to 2014, comparing the rate of age-adjusted traffic fatalities in Hawaii with the national trend of declining fatalities. When adjusting for miles driven per licensed driver and other covariates including population demographics, traffic laws,

TABLE 2. Description of Drivers Killed in Traffic Crashes in Hawaii, by Status of Cannabinoid (THC) Testing, 2011–2015 (n = 283)

	THC Positive (+)	THC Negative (−)	Not Tested/Unknown	*P* value THC (+)vs. (−)
No. drivers	46	215	22	
Vehicle type				
Car/truck	54% (25)	50% (108)	36% (8)	
Motorcycle/moped	46% (21)	50% (107)	64% (14)	0.61
Age (mean ± SD)	32 ± 13	42 ± 18	45 ± 23	<0.001
Male gender	83% (38)	87% (187)	82% (18)	0.45
Positive for meth, total	7% (3)	8% (17)	0	0.74
Positive for meth, tested	7% (3)	8% (17)	0	0.74
Positive for alcohol, total	67% (31)	41% (89)	27% (6)	0.004
Positive for alcohol, tested	67% (31)	42% (89)	86% (6)	0.002
Weekend crash (Saturday-Sunday)	41% (19)	40% (86)	41% (9)	0.87
Nighttime crash (6:31 PM to 6:29 AM)	72% (33)	49% (105)	36% (8)	0.005
Single-vehicle crash	67% (31)	50% (101)	41% (9)	0.011
Speeding	74% (34)	51% (110)	45% (10)	0.004
Safety devices (seat belts, helmets)				
used	24% (11)	39% (83)	41% (9)	
not used	70% (32)	51% (110)	50% (11)	0.035

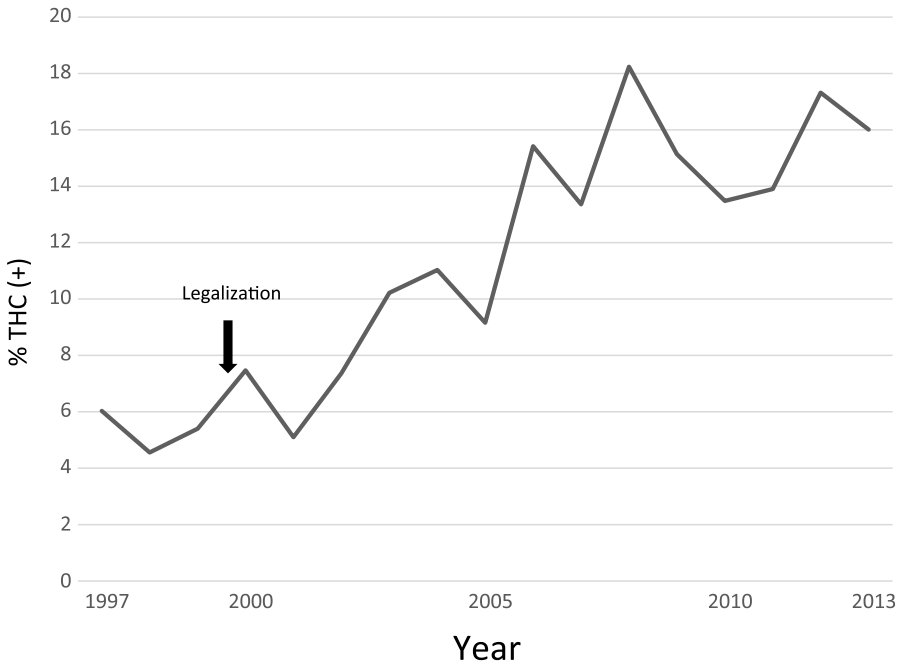

Figure 2. Incidence of cannabis (THC) positivity in trauma patients evaluated at the state's highest level trauma center.

driving safety laws, and law enforcement and safety expenditures, they found legalization of marijuana to be associated with an overall increase in fatality rates (0.04 deaths/100,000). However, this increase did not reach statistical significance, and the trend appeared to reverse by 2014. Thus, despite a threefold increase in THC positivity among driver fatalities, it is difficult to draw a definite conclusion regarding the impact of marijuana legalization on overall traffic fatality rate.

The rate of THC positivity in fatally injured drivers in Hawaii has continued to trend upward in recent years, in contrast to most other states with legalized cannabis.[19] Additionally, Hawaii's alcohol-positive fatality rate has remained relatively stable with the introduction of legal cannabis. This is in contrast to other legal cannabis states[19] and contradicts the hypothesis that users will substitute cannabis for alcohol.[20] Our data confirm that over two thirds of fatally injured, THC-positive drivers also consumed alcohol. Alcohol exacerbates the neurocognitive effects of cannabis, particularly regarding impaired driving.[5,14] This may contribute to the increasing rate of THC-associated fatalities in Hawaii.

The percentage of adults in Hawaii who report marijuana use within the past 30 days is less than half of the frequency of

TABLE 3. State Trauma Registry Data on Motor Vehicle Crashes From 2011 Through 2015 Comparing THC-Positive Versus THC-Negative Drivers (n = 2,512)

	THC Positive (+)	THC Negative (−)	Not Tested/Unknown	*P* THC (+) vs. (−)
No. drivers	322	1,050	1,140	
Vehicle type				
Car/truck	40% (130)	52% (550)	54% (620)	
Motorcycle/moped	60% (192)	48% (500)	46% (520)	<0.001
Age (mean ± SD)	35 ± 14	41 ± 17	40 ± 18	<0.001
Male sex	87% (279)	76% (796)	70% (802)	<0.001
Positive for alcohol, total	39% (125)	24% (264)	13% (149)	<0.001
Positive for alcohol, tested	39% (125)	25% (264)	36% (149)	<0.001
Safety devices (seat belts, helmets)				
Used	33% (106)	56% (590)	63% (716)	
Not used	61% (197)	40% (419)	34% (390)	<0.001
Payer				
No fault auto/commercial/private	60% (192)	63% (658)	68% (771)	0.33
Medicaid	28% (90)	14% (146)	9% (105)	<0.001
Medicare/Department of Defense/other government	5% (15)	16% (171)	15% (173)	<0.001
Self pay	7% (23)	5% (56)	6% (71)	0.22
Worker's compensation/other	1% (2)	2% (19)	2% (20)	0.19

THC positivity in driver fatalities and in patients presenting to the highest level trauma center.[21] This loosely suggests that cannabis may be associated with increased odds of traumatic injury, though substantially confounded by use of self-reported data for cannabis use. We cannot conclude that cannabis use is an independent risk factor for injury or death from our data alone.

THC undergoes complex order metabolism dependent on the route, amount and time of ingestion, and redistribution from fat stores. Chronic, heavy users may have THC detected in the urine for weeks following last marijuana use.[22] Unlike alcohol, THC levels cannot be extrapolated back to determine the THC level at the time of a crash. The threshold for a "positive" THC screening test at Hawaii trauma centers is equal to the cutoff level for federal workplaces (50 ng/mL) and is specific for primary use, rather than second-hand smoke exposure.[23] However, a serum THC level as low as 5 ng/mL is correlated with cognitive impairment and is the threshold for DUIC in Washington and Colorado.[13,24] Thus, our series likely contains a number of false-negative THC results in drivers who were cognitively impaired, due to the high screening threshold, and the absence of confirmatory analysis in fatalities who screened positive only for THC. Our data were also unable to differentiate between acute cannabis intoxication and chronic heavy use, although both groups may demonstrate cognitive impairment.[13] Some authorities suggest that combined observations on psychophysical and eye exams by a Drug Recognition Expert be used in addition to toxicology testing.[25]

In corroboration of Lowenstein and Koziol-McLain's[16] study, our data shows that THC-positive drivers are younger, more often involved in single-vehicle crashes, and less likely to use protective devices, such as seatbelts and helmets. This may be an additional cause of cannabis-associated mortality, particularly in states like Hawaii which lack helmet laws.[26] There is a public financial burden of caring for unhelmeted riders, who are significantly more likely to be hospitalized, incur charges greater than US $25,000, and be uninsured or underinsured.[27]

The health care financial burden is reiterated as current data demonstrate that cannabis users in motor vehicle crashes are twice as likely to have Medicaid insurance. Persistent use of cannabis is associated with unemployment and lower prestige (lower paying) occupations.[28,29] Uncompensated emergency department costs, perhaps millions of dollars per hospital annually, due to the medical complications of cannabis have been recognized.[6] While these medical emergency department losses may be tolerable, the costs of cannabis-related trauma—particularly MVC and DUIC—may be a "first-order concern."[8] Despite state Medicaid expenses of US $500 to 800 million per year, only an estimated 70% to 83% of inpatient hospital costs were covered.[30,31] The low Medicaid reimbursement rates for trauma were corroborated by contemporary reports from other states.[32,33]

In conclusion, since legalization of medical marijuana in Hawaii, THC positivity among driver fatalities has nearly tripled statewide, and THC positivity among patients presenting to the highest level trauma center has doubled. This study demonstrates a dramatic and sustained increase in THC positivity in motor vehicle crash injuries and fatalities in the state of Hawaii, coincident with the legalization of marijuana. High risk behavior may contribute, as single-vehicle crashes, speeding, and lack of seatbelt and helmet use were significantly higher in THC-positive fatalities. Cannabis users were younger, and almost twice as likely to rely on public funding for the costs of their trauma care. Our data are insufficient to demonstrate causality between cannabis use and crashes, nor does it prove that cannabis is an independent risk factor for injury or death. Nevertheless, the associations presented may raise awareness, and underscore the need for further research, particularly regarding relative risk of injury, and indicators of impairment due to cannabis alone or in combination with alcohol. These data, moreover, suggest there is a broad need for further investigation and policy development to address the public health effects and the costs of cannabis-related trauma.

AUTHORSHIP

S.S. contributed to study design, analysis and interpretation of data, drafting of the article. D.G. and W.B. contributed to study design, analysis and interpretation of data, drafting and critical revision of the article. T.N. contributed to analysis and interpretation of data, drafting and critical revision of the article.

The views expressed are those of the authors and do not necessarily represent the official policy or views of the Queen's Medical Center or Hawaii Department of Health.

There was no funding received for this work, and the authors disclose no conflict of interests relevant to this research.

This research was presented as a Quick Shot presentation at the 76th Annual Meeting of AAST and Clinical Congress for Acute Care Surgery, September 13–16, 2017 in Baltimore, Maryland.

DISCLOSURE

The authors declare no conflicts of interest.

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