Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

HHS Public Access

Author manuscript

Drug Alcohol Depend. Author manuscript; available in PMC 2023 January 30.

Published in final edited form as:

Drug Alcohol Depend. 2022 March 01; 232: 109288. doi:10.1016/j.drugalcdep.2022.109288.

Trends and characteristics of cannabis-associated emergency department visits in the United States, 2006–2018

Douglas R. Roehler[*],
Brooke E. Hoots,
Kristin M. Holland,
Grant T. Baldwin,
Alana M. Vivolo-Kantor

Division of Overdose Prevention, National Center for Injury Prevention and Control, Centers for Disease Control and Prevention, Atlanta, GA, United States

Abstract

Background: Cannabis policies are rapidly changing in the United States, yet little is known about how this has affected cannabis-associated emergency department (ED) visits.

Methods: We studied trends in cannabis-associated ED visits and identified differences by visit characteristics. Cannabis-associated ED visits from 2006 to 2018 were identified from the Agency for Healthcare Research and Quality's Healthcare Cost and Utilization Project's (HCUP) Nationwide Emergency Department Sample (NEDS). JoinPoint analysis was used to identify trends from 2006 to 2014, prior to medical coding changes in 2015, and Z-tests were used to compare annual rate changes from 2016 to 2018. Changes in rates from 2017 to 2018 were examined by visit characteristics.

Results: From 2006–2014, the rate of cannabis-associated ED visits increased, on average, 12.1% annually ($p < 0.05$), from 12.3 to 34.7 visits per 100,000 population. The rate increased 17.3% from 2016 to 2017 ($p < 0.05$) and 11.1% from 2017 to 2018 ($p < 0.05$). From 2017–2018, rates of visits increased for both males (8.7%; $p < 0.05$) and females (15.9%; $p < 0.05$). Patients 0–14 years and 25 years and older had significant rate increases from 2017 to 2018 as did the Midwest region (36.8%; $p < 0.05$), the Northeast (9.2%; $p < 0.05$), and the South (4.5%; $p < 0.05$).

Conclusions: Cannabis-associated ED visits are on the rise and subgroups are at increased risk. Some potential explanations for increases in cannabis-associated ED visits include increased availability of cannabis products, increased use, and diversity of products available

[*]Correspondence to: Division of Overdose Prevention, National Center for Injury Prevention and Control, Centers for Disease Control and Prevention, MS: S106-8, 4770 Buford Highway NE, Atlanta, GA 30341, United States., droehler@cdc.gov (D.R. Roehler).

Contributors

DR designed the research idea and wrote the manuscript. BH analyzed the data and reviewed the manuscript. KH provide subject matter expertise and reviewed the manuscript. GB came up with the initial study idea and reviewed the manuscript. AVK designed the research idea and reviewed the manuscript. All authors have contributed to and approved the finial manuscript.

Disclaimer

The findings and conclusions in this paper are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

Conflict of Interest

The authors have no conflicts to disclose.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

in marketplaces. Strategies are needed to prevent youth initiation, limit potentially harmful use among adults, and ensure safe storage where cannabis use is legal.

Keywords

Cannabis; Surveillance; Emergency medicine

1. Introduction

Cannabis is the most widely used federally illicit substance in the United States and its use is on the rise (Substance Abuse and Mental Health Services Administration, 2020). As of October 2021, 18 states, 2 territories, and the District of Columbia (DC) have legalized small amounts of cannabis for nonmedical adult use, and 36 states, 3 territories, and DC allow cannabis for medical use (National Concil of State Legislatures. State Medical Marijuana Laws, 2020). For comparison, in 2006, no state or territory allowed for nonmedical adult use and 12 allowed for some form of medical cannabis use (National Concil of State Legislatures. State Medical Marijuana Laws, 2020). According to the National Survey on Drug Use and Health (NSDUH), the percentage of Americans aged 12 years and older who reported past-year marijuana use demonstrated a marked 70% increase between 2006 and 2019, from 10.3% (25.4 million people) to 17.5% (48.2 million people). As cannabis legalization and use have increased across the country, the perception that cannabis is dangerous or can be harmful has decreased, especially among youth (Brooks-Russell et al., 2019; Salloum et al., 2018).

In addition to increased availability and use, the delta-9-tetrahydrocannabinol (THC) concentration of cannabis has been on the rise in recent decades (Cascini et al., 2012; Hall and Lynskey, 2016; NIDA, 2019). This is particularly concerning because increased THC, one of the intoxicating components of cannabis, is associated with increased health risk, such as acute mental health episodes (Chandra et al., 2019; Englund et al., 2017; Schoeler et al., 2016). Some researchers have found associations between use of cannabis with high concentrations of THC and increased dependence and severity of dependence, especially when use begins in adolescence (Freeman and Winstock, 2015). Between 2002 and 2011, cannabis abuse and cannabis dependence diagnoses were found to be increasing in the inpatient population, trending toward older and sicker patients with moderate to severe disability (Charilaou et al., 2017). Between 1997 and 2014, average hospitalization rates for marijuana abuse and dependence increased from 4.49 to 16.04 per 1000 discharges (Shi, 2017). In another study, Shen et al. investigated cannabis-associated ED visits between 2006 and 2014 while adjusting for year, patient, and hospital characteristics, and found 7% increased odds of cannabis-associated ED visits with each year (Shen et al., 2019).

As cannabis use and THC concentrations increase in the US in parallel with legalization and decriminalization in many states, it is imperative to monitor cannabis-associated health effects, particularly given existing evidence to support both therapeutic and harmful health effects of cannabis use. Studies have documented mixed therapeutic use of cannabis to alleviate symptoms of multiple sclerosis and chronic pain (Baker et al., 2003; McDonagh et al., 2020; Rog et al., 2005; Zajicek et al., 2012). Synthesized THC has been approved by

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

the U.S. Food and Drug Administration (FDA) to relieve nausea caused by chemotherapy and to stimulate appetite for individuals suffering from wasting syndrome (DeJesus et al., 2007; Ware et al., 2008). Additionally, concentrated cannabidiol (CBD), a nonintoxicating compound of cannabis, has been approved as a prescription medication by the FDA to treat rare seizure disorders (Elliott et al., 2019). In contrast, risks associated with cannabis use have also been identified, in particular for early initiators and individuals who use regularly (Hall and Degenhardt, 2009; Volkow et al., 2014). For example, some studies indicate that among youth who use marijuana, especially those considered heavy consumers, marijuana use affects the developing brain (Levine et al., 2017; Zalesky et al., 2012). Use of marijuana in adolescence or young adulthood has been found to be associated with lower IQ and graduation rates (Meier et al., 2012; Silins et al., 2014). Studies show that cannabis use may impair psychomotor skills, slows reaction time, and harms working memory and other skills that are necessary for safe driving (Desrosiers et al., 2015; Hartman et al., 2015; Ramaekers et al., 2009). In addition, a recent national outbreak of e-cigarette or vaping product use associated lung injury (or EVALI) was driven primarily by additives to THC-containing products obtained from informal sources like friends, family, or in-person or online dealers (King et al., 2020). However, the state of the literature on adverse health effects is not unified and more rigorous research is needed.

Our understanding of the health effects of marijuana use continues to evolve, but current research suggests that increases in availability, use, THC concentration, and changing modes of use (e.g., edibles, vapes, dabs) may lead to further increases in emergency department visits (Marx et al., 2019; Wang et al., 2018). To better understand the morbidity associated with marijuana use, we 1) investigated annual changes in rates of cannabis-associated ED visits from 2006 to 2018, and 2) examined recent changes in rates (from 2017 to 2018) by ED visit characteristics. While cannabis-associated ED visits from 2006 to 2014 have previously been described by Shen et al., our analysis presents age-adjusted rates of cannabis-associated ED visits by year using a more conservative case definition for the entire Nationwide Emergency Department Sample (NEDS) weighted annual samples (as opposed to random samples of the NEDS annual samples) and are presented here for comparison to data for more recent years not presented in Shen et al. While the Shen et al. study is an important contribution to the literature, the current study may better reflect true cases of cannabis-associated ED visits that are representative of the US population.

2. Materials and methods

2.1. Study sample

Study data come from the Agency for Healthcare Research and Quality's Healthcare Cost and Utilization Project's (HCUP) Nationwide Emergency Department Sample (NEDS) survey from 2006 to 2018. The NEDS is sampled from the State Inpatient Databases (SID) and State Emergency Department Databases (SEDD). The SID contain information on patients initially seen in the ED and subsequently admitted to the same hospital, while the SEDD capture information on ED visits that do not result in admission. Additional details on the SID and SEDD can be found elsewhere (NEDS Database Documentation, n.d.). The NEDS data contain de-identified patient information for diagnoses, procedures,

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

demographics, length of stay, admission and discharge status, hospital charges, and payment sources (Agency for Healthcare Research and Quality, 2014). A stratified random sampling procedure is used to produce nationally representative estimates for the United States. From 2006–2018, a range of facilities (i.e., 945–984) and states (i.e., 24–37 states and Washington, D.C.) participated in the NEDS (35). This study is based on publicly available anonymized data, and thus exempt from ethical compliance.

Measures.—The primary outcome – cannabis-associated ED visits – was defined based on International Classification of Diseases, 9th Revision, Clinical Modification (ICD–9–CM) and 10th Revision, Clinical Modification (ICD-10-CM) diagnostic codes. ICD-9-CM codes included those categorized under 304.3 (i.e., cannabis dependence) and 305.2 (i.e., nondependent cannabis abuse), excluding codes for “dependence in remission” and “abuse in remission.” Beginning October 1, 2015, coding practices transitioned to ICD-10-CM and expanded the number of codes available for a range of drugs. Thus, the ICD-10-CM codes for this study include codes categorized under both use (i.e., F12 - cannabis-associated disorders including cannabis abuse [F12.1], cannabis dependence [F12.2], and cannabis use, unspecified [F12.9]) and poisonings (i.e., T40.7X – poisoning by, adverse effect or an underdosing of cannabis). Codes indicating “in remission” and “withdrawal” were excluded. All encounter types (i.e., initial [A], subsequent [D], and sequelae [S] in the 7th character of the code) and most intent types (i.e. unintentional, intentional self-harm, assault, undetermined, and adverse effect) were included. All diagnoses, not just the primary listed diagnosis code, were included. Underdosing intent was excluded. Several patient and hospital characteristics were included as covariables: sex, age group, hospital census region (i.e., Northeast, Midwest, South, West), hospital county urbanization level (i.e., large central metro, large fringe metro, medium metro, small metro, micropolitan, noncore), hospital admission status, mortality status, and payor type.

2.2. Statistical analysis

First, we examined annual trends in rates of cannabis-associated ED visits. Because of the shift from ICD–9–CM to ICD–10–CM in the fourth quarter of 2015, we only examined the trend from 2006 through 2014 and did not include the year 2015 in the trend analysis. Relative percent change was calculated separately between rates for 2016–2017 and 2017–2018 for ED visits with ICD–10–CM diagnosis codes since only three time points were available and a trend could not be assessed post-2015. Z-tests were used to compare changes in rates between years, with p-values < 0.05 considered statistically significant. Age-adjusted rates per 10,000 population were calculated by applying age-specific rates to the 2000 U.S. Census standard population age distribution. Potential joins in the trend from 2006 to 2014 were investigated using JoinPoint software (https://surveillance.cancer.gov/joinpoint/). Join points, or points (in this case, years) where there is a statistically significant change in trend from previous years, are obtained using a permutation test via Monte Carlo resampling. Predicted trend lines were fit using weighted binomial regression in SAS-callable SUDAAN around any identified joins with year as the independent variable and rate of cannabis-associated ED visits as the dependent variable. Sample weights were adjusted to reflect the age adjustment in the rates (Ingram et al., 2018). A prevalence ratio (PR) with

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

95% confidence interval (95% CI) estimating the change in the rate of cannabis-associated ED visits associated with a 1-year increase was estimated from the binomial regression.

Subsequent analyses calculated absolute and relative rate changes between the two most recent years, 2017–2018. Overall changes were assessed as well as change by patient and hospital characteristics for cannabis-associated ED visits. Z-tests were used to compare changes from 2017–2018. Analyses were conducted using SAS (version 9.4; SAS Institute) to account for HCUP's complex survey design and weighting.

3. Results

The rate of cannabis-associated ED visits steadily increased from 12.3 visits per 100,000 population in 2006 to 34.7 visits per 100,000 in 2014 (Fig. 1), with an average annual increase of 12.1% over this time period (PR=1.12, 95% CI: 1.120, 1.122). No joins were identified, indicating a constant trend from 2006 to 2014. From 2016–2017, the rate of cannabis-associated ED visits increased from 41.6 to 48.8 visits per 100,000 (17.3%, $p < 0.05$). The rate increased further from 2017 to 2018, from 48.8 to 54.2 visits per 100,000 (11.1%, $p < 0.05$).

In 2018, there were 1,732,605 cannabis-associated ED visits in the United States (Table 1). Between 2017 and 2018, the relative percent increase in the rate of cannabis-associated ED visits was 15.9% among females (from 36.5 to 42.3 per 10,000) and 8.7% among males (from 61.2 to 66.5 per 10,000). Patients 0–14 years and those 25 and older also saw significant relative rate increases between 2017 and 2018, although the absolute rate increase for patients 0–14 years was small (0.4 per 10,000). For patients 25 and older, relative rate increases ranged between 9.5% for those ages 25–34 and 24.8% for those 65 and older. The Midwest (36.8%), Northeast (9.2%), and South (4.5%) all experienced significant relative rate increases between 2017 and 2018, as did small metro (30.4%), large fringe metro (20.8%), medium metro (7.7%), and large central metro (4.6%) urbanization levels.

From 2017–2018, the relative percent increase in the rate of cannabis-associated ED visits admitted to the hospital was 3.1% (from 19.2 to 19.8 per 10,000). In 2017, 297 cannabis-associated emergency department patients died (0.02% of all visits), and in 2018 there were 374 deaths (0.02% of all visits) (data not shown).

4. Discussion

The current study investigated trends in rates of cannabis-associated ED visits from 2006 to 2014 and relative percentage change in rates from 2016 to 2018. We found a significant annual increase in rates of cannabis-associated ED visits from 2006 to 2014 and annual percentage increases from 2016 to 2018. We also identified differences in rate changes by visit characteristics. Most notable were findings that indicate significant increases across both sexes, most age groups, and most Census regions and county urbanization levels.

There are several potential explanations that, when taken together, may account for the increased rate of cannabis-associated ED-visits. First, the number of Americans aged 12 and older who reported using marijuana in the past year increased from 25.4 million people in

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

2006 to 48.2 million people in 2019—a 70% increase (Substance Abuse and Mental Health Services Administration, 2020), and this increase coincided with a time when Americans increasingly gained legal access to medicinal and non-medicinal marijuana at the state level (National Concil of State Legislatures. State Medical Marijuana Laws, 2020). As of October 2021, over two-thirds of Americans live in a state with medicinal access, and nearly 30% live in a state with non-medicinal cannabis access; these percentages continue to rise (Bureau, 2018; National Concil of State Legislatures. State Medical Marijuana Laws, 2020). All the while, in 2019 only 29.2% of American 12 years and older believe smoking marijuana once or twice a week is a great risk of harm, which is down from 51.2% in 2006 (Substance Abuse and Mental Health Services Administration, 2020). This change in perceived risk has occurred while the US has experienced a 68.6% increase in the number of people aged 12 and older initiating cannabis use between 2006 and 2019, (approximately 9500 new initiates per day in 2019 (Substance Abuse and Mental Health Services Administration, 2020)). These findings may underline previous research demonstrating that as perception of risk decreases, cannabis use increases (Bachman et al., 1998).

Second, as previously mentioned, the THC concentration of available cannabis is on the rise. From 2008–2017, the mean percent THC concentration in all seized marijuana products almost doubled from 8.9% to 17.1%, and the increase is even greater in the most concentrated products like hash oil which increased 9-fold (Chandra et al., 2019). Further, THC-containing e-cigarette or vaping product use, a mode of use that facilitates the consumption of highly concentrated THC, is surging. The increase in THC-containing e-cigarette or vaping among high school and college-aged adolescents and young adults is particularly concerning given the still developing brain and the elevated risk of frequent use of high concentration vape oils progressing into a substance use disorder in adulthood (Levine et al., 2017; Miech et al., 2020). Over 22% of 12th graders and 24% of full-time college students reported past year “marijuana vaping” in 2020 (Johnston et al., 2021). The growing number of people who report newly initiating cannabis is also concerning (Substance Abuse and Mental Health Services Administration, 2019), as new initiates may lack knowledge of the concentration of their products and may inadvertently use too much (Freeman et al., 2014). These surges contributed to the recent EVALI outbreak, which was driven primarily by additives to THC-containing products obtained from informal sources (King et al., 2020).

Finally, more Americans have access to more product types, and the patterns of cannabis use are evolving (Kumar et al., 2019). Edibles and concentrates continue to increase in popularity across the U.S. (Caulkins et al., 2015; Patrick et al., 2020). These increases raise the likelihood of unintended exposures – such as among children – and these different product types have differential symptomology (Cao et al., 2016; Grotenhermen, 2003). For example, some may overconsume edibles before feeling the psychoactive properties of THC. Compared to inhaled cannabis where the effects of THC occur nearly instantly, when marijuana is orally ingested, the psychoactive effects can take 30–90 minutes to manifest (Grotenhermen, 2003). Consequently, people who ingest cannabis may experience the deleterious health effects of high levels of THC consumption resulting in the need for medical attention, such as social anxiety, panic attacks, and elevated heart rate

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

(Blanco et al., 2016; Bui et al., 2015; Hudak et al., 2015). Also, increased use of higher concentration products via e-cigarette, vaping, or dabbing products is associated with more frequent use (Barrington-Trimis et al., 2020), which can, in turn, increase the likelihood of overconsumption. Dabbing is the act of inhaling vaporized cannabis concentrates using a heating tool such as a dab rig or a vaporizer, often resulting in inhalation of much higher concentrations of THC compared to other forms of using cannabis (Raber et al., 2015). Research suggests that dabbing may result in higher rates of tolerance and risk of dependance, compared to other forms of consumption (Loflin and Earleywine, 2014). In short, shifts in exposure, concentration, and modalities, may be driving the increase in ED visits. More research is warranted to understand the contribution of these factors to increases in care-seeking, and to better understand if the findings are due to increased prevalence of use and different modes of use, or if the products are becoming more dangerous to consumers.

Adults 55 years and older had the largest percent change increases for cannabis-associated ED visits between 2017 and 2018 compared to all other age groups. This finding aligns with increased cannabis use among adults aged 55 years and older during this time period (Maxwell et al., 2021). In addition to rising cannabis use among this population, the increased cannabis-associated ED visits could also be a byproduct of other comorbidities associated with age. Although more research is needed to investigate this subpopulation, there are known drug-drug interactions of cannabinoids with some prescription medications, and caution should be heeded to monitor possible reactions among individuals who use cannabis and are taking medications, especially among those with chronic conditions and the elderly (Alsherbiny and Li, 2019).

Our analyses also indicated increases among different urbanization levels. For example, all metropolitan categories experienced increases in cannabis-associated ED visits. We hypothesize there are greater numbers and densities of dispenseries in these areas and may therefore increase cannabis-associated ED visits. This hypothesis is based on research that finds a relationship between alcohol outlet density, especially in urban communities, and negative health outcomes (Campbell et al., 2009; Guide to Community Preventive Services. CPSTF Findings for Excessive Alcohol Consumption, 2021; Morrison et al., 2016). Research is needed to determine whether this relationship also exists for cannabis. There was also geographic variation in our findings. For example, between 2017 and 2018, cannabis-associated ED visits increased in the South (4.5%), Northeast (9.2%), and Midwest (36.8%), with no significant change for the West. While analysis of the relationship between state-level cannabis policy and cannabis-associated ED visits was beyond the scope of this paper, cannabis use and cannabis use disorder have increased in some states with medical and non-medical adult legalization (Hasin et al., 2017; Kosterman et al., 2016). However, it is well understood that cannabis marketplaces experience surges in sales when first opened, and over time stabilize (Firth et al., 2020; Smart et al., 2017). It is possible that the increases in cannabis-associated ED visits are not observed in the West due to the West having a higher proportion of states with both legalized medical and nonmedical adult cannabis use for a longer period of time and therefore stabilization of novice users may have occurred; the small increase in the South could reflect the absence of legalization in this region. Future

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

research is needed to tease out why these differences have occurred and whether specific strategies can be implemented to reduced cannabis-related ED visits.

More research on the health and social effects of cannabis use, as well as the short- and long-term risks of cannabis use, are warranted. The current understanding of risks associated with use during childhood and adolescence, prolonged and frequent use of cannabis products – particularly more concentrated ones, – and the growing legalization of cannabis across the US support the need for targeted prevention strategies. The development and implementation of evidence-based harm reduction strategies may significantly reduce cannabis-related morbidity; for example, strategies to prevent initiation among youth, reduce harmful use among adults, and ensure safe product storage in states where cannabis use is legal. As with other substance use and injury topics, comprehensive prevention efforts that address societal-, community-, relationship-, and individual-level risk and protective factors may be most effective in preventing adverse effects of cannabis use. For instance, upstream implementation of universal, evidence-based substance use prevention strategies during youth, such as Life Skills Training, have demonstrated effectiveness at preventing cannabis use and use of other substances through young adulthood (Tremblay et al., 2020). Such strategies may be useful in preventing initiation and use in age groups where the highest cannabis-associated ED visits were observed (i.e., 15–34 year-olds). More research is needed for policies implemented at the societal and community levels. As mentioned, researchers have identified relationships between alcohol outlet density and associated harms, and studies could be conducted to investigate if similar patterns exist for cannabis dispensary density (Campbell et al., 2009). While imparting heavy taxes on retail alcohol use has been successful at deterring consumption, similar studies could be conducted on heavy retail cannabis taxes and potentially harmful use to determine their success with retail cannabis (Elder et al., 2010). Further, safe storage of medications and other potentially harmful products has demonstrated effectiveness in preventing poisonings (Achana et al., 2015); expansion of this prevention strategy to include safely storing cannabis out of youth's reach in a locked container may prove useful for preventing unintentional cannabis ingestion in particular. While such cases contributed to only a small proportion of the ED visits examined, there was a 17.4% increase in ED visits for youth aged 0–14 years between 2017 and 2018, and as poison control center calls for this age group are also on the rise, sharing messages and educational materials around safe storage of cannabis may help reduce cannabis-associated ED visits among this most vulnerable age group (Thomas et al., 2019; Wang et al., 2014; Whitehill et al., 2019).

4.1. Limitations

Our study has several noted limitations. First, the transition from ICD-9-CM diagnostic coding to the current standard of ICD-10-CM occurred during the study period in October 2015. Thus, we were unable to assess the trend over the entire time period and instead examined pairwise annual increases post-2015. The transition from ICD-9-CM to ICD-10-CM may have contributed to subsequent increases in rates of cannabis-involved ED visits after 2015 if ICD-10-CM codes captured ED visits missed by ICD-9-CM codes. However, previous analyses looking at the effect of the coding transition on opioid-related inpatient stays in hospital discharge data did not find that the transition led to increases in visits

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

in all states examined (Heslin et al., 2017; Yang et al., 2021). In addition, we included all diagnoses, not just the primary listed diagnosis code. This may have resulted in an overestimation of true cannabis-associated ED visits; however, this was applied consistently across time. Specific ICD-9-CM and ICD-10-CM codes included are general to cannabis use, “abuse,” “dependence,” or “poisoning,” limiting our ability to understand the type of cannabis used (e.g., marijuana, CBD oil, synthetic cannabinoids). Though the discharge diagnosis codes are standardized, coding practices may vary across facilities affecting the rates presented. As with any administrative database, coding inaccuracies may occur given the coding is reliant on clinician’s documentation and the medical coders’ experience (O’malley et al., 2005). Our data include unique events and not individuals; thus we may have included repeat ED visits. We were also limited in our analysis by the data available through HCUP. For example, we were unable to analyze by medical versus nonmedical cannabis use by the patient, THC detection in urinalysis of the patient, or by the primary diagnosis/chief complaint for the visit. Furthermore, the study period ends in 2018 given these are the most recent data available at the time of analysis. Lastly, while an analysis of the relationship between state-level cannabis policy and cannabis-associated ED visits is important to better design and tailor interventions, it is beyond the scope of this paper. To investigate this important research question, careful and nuanced attention to each state’s unique policies is warranted. Given the diversity of state policies and dates of implementation, a separate policy analyses are warranted.

5. Conclusion

As cannabis use increases across the U.S., cannabis-associated ED visits have also increased. Between 2006 and 2014, the average annual increase in the rate of cannabis-associated ED visits was 12.1%. The rate increased 17.3% from 2016 to 2017 and 11.1% from 2017 to 2018. Furthermore, for youth, the rate increased 17.4% from 2017 to 2018. Given these increases, strategies are needed to prevent initiation among youth, limit potentially harmful use among adults, and ensure safe storage where cannabis use is legal at the state level.

References

Achana FA, Sutton AJ, Kendrick D, Wynn P, Young B, Jones DR, Hubbard SJ, Cooper NJ, 2015. The effectiveness of different interventions to promote poison prevention behaviours in households with children: a network meta-analysis. PLoS One 10 (4), e0121122. [PubMed: 25894385]

Agency for Healthcare Research and Quality, 2014. HCUP NEDS Database Documentation. Healthcare Cost and Utilization Project (HCUP). Rockville, MD. (Accessed 12 October 2021).

Alsherbiny MA, Li CG, 2019. Medicinal cannabis-potential drug interactions. Medicines 6 (1), 3.

Bachman JG, Johnson LD, O’Malley PM, 1998. Explaining recent increases in students’ marijuana use: impacts of perceived risks and disapproval, 1976 through 1996. Am. J. Public Health 88 (6), 887–892. [PubMed: 9618614]

Baker D, Pryce G, Giovannoni G, Thompson A, 2003. The therapeutic potential of cannabis. Lancet Neurol. 2 (5), 291–298. [PubMed: 12849183]

Barrington-Trimis JL, Cho J, Ewusi-Boisvert E, Hasin D, Unger JB, Miech RA, Leventhal AM, 2020. Risk of persistence and progression of use of 5 cannabis products after experimentation among adolescents. JAMA Netw. Open 3 (1), e1919792. –e1919792. [PubMed: 31977062]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Blanco C, Hasin DS, Wall MM, Flórez-Salamanca L, Hoertel N, Wang S, Kerridge BT, Olfson M, 2016. Cannabis use and risk of psychiatric disorders: prospective evidence from a US national longitudinal study. JAMA Psychiatry 73 (4), 388–395. [PubMed: 26886046]

Brooks-Russell A, Ma M, Levinson AH, Kattari L, Kirchner T, Goodell EMA, Johnson RM, 2019. Adolescent marijuana use, marijuana-related perceptions, and use of other substances before and after initiation of retail marijuana sales in Colorado (2013–2015). Prev. Sci. 20 (2), 185–193. [PubMed: 30043198]

Bui QM, Simpson S, Nordstrom K, 2015. Psychiatric and medical management of marijuana intoxication in the emergency department. West. J. Emerg. Med. 16 (3), 414–417. [PubMed: 25987916]

Campbell CA, Hahn RA, Elder R, Brewer R, Chattopadhyay S, Fielding J, Naimi TS, Toomey T, Lawrence B, Middleton JC, 2009. The effectiveness of limiting alcohol outlet density as a means of reducing excessive alcohol consumption and alcohol-related harms. Am. J. Prev. Med. 37 (6), 556–569. [PubMed: 19944925]

Cao D, Srisuma S, Bronstein AC, Hoyte CO, 2016. Characterization of edible marijuana product exposures reported to United States poison centers. Clin. Toxicol. 54 (9), 840–846.

Cascini F, Aiello C, Di Tanna G, 2012. Increasing delta-9-tetrahydrocannabinol (Δ-9-THC) content in herbal cannabis over time: systematic review and meta-analysis. Curr. Drug Abus. Rev. 5 (1), 32–40.

Caulkins JP, Kilmer B, Reuter PH, Midgette G, 2015. Cocaine's fall and marijuana's rise: questions and insights based on new estimates of consumption and expenditures in US drug markets. Addiction 110 (5), 728–736. [PubMed: 25039446]

Chandra S, Radwan MM, Majumdar CG, Church JC, Freeman TP, ElSohly MA, 2019. New trends in cannabis potency in USA and Europe during the last decade (2008–2017). Eur. Arch. Psychiatry Clin. Neurosci. 269 (1), 5–15. [PubMed: 30671616]

Charilaou P, Agnihotri K, Garcia P, Badheka A, Frenia D, Yegneswaran B, 2017. Trends of cannabis use disorder in the inpatient: 2002 to 2011. Am. J. Med. 130 (6), 678–687 e677. [PubMed: 28161344]

DeJesus E, Rodwick BM, Bowers D, Cohen CJ, Pearce D, 2007. Use of dronabinol improves appetite and reverses weight loss in HIV/AIDS-infected patients. J. Int. Assoc. Physicians AIDS Care 6 (2), 95–100.

Desrosiers NA, Ramaekers JG, Chauchard E, Gorelick DA, Huestis MA, 2015. Smoked cannabis' psychomotor and neurocognitive effects in occasional and frequent smokers. J. Anal. Toxicol. 39 (4), 251–261. [PubMed: 25745105]

Elder RW, Lawrence B, Ferguson A, Naimi TS, Brewer RD, Chattopadhyay SK, Toomey TL, Fielding JE, Services TFo.C.P., 2010. The effectiveness of tax policy interventions for reducing excessive alcohol consumption and related harms. Am. J. Prev. Med. 38 (2), 217–229. [PubMed: 20117579]

Elliott J, DeJean D, Clifford T, Coyle D, Potter BK, Skidmore B, Alexander C, Repetski AE, Shukla V, McCoy B, 2019. Cannabis-based products for pediatric epilepsy: a systematic review. Epilepsia 60 (1), 6–19. [PubMed: 30515765]

Englund A, Freeman TP, Murray RM, McGuire P, 2017. Can we make cannabis safer? Lancet Psychiatry 4 (8), 643–648. [PubMed: 28259650]

Firth CL, Davenport S, Smart R, Dilley JA, 2020. How high: differences in the developments of cannabis markets in two legalized states. Int. J. Drug Policy 75, 102611. [PubMed: 31786435]

Freeman T, Winstock A, 2015. Examining the profile of high-potency cannabis and its association with severity of cannabis dependence. Psychol. Med. 45 (15), 3181–3189. [PubMed: 26213314]

Freeman TP, Morgan CJ, Hindocha C, Schafer G, Das RK, Curran HV, 2014. Just say 'know': how do cannabinoid concentrations influence users' estimates of cannabis potency and the amount they roll in joints? Addiction 109 (10), 1686–1694. [PubMed: 24894801]

Grotenhermen F, 2003. Pharmacokinetics and pharmacodynamics of cannabinoids. Clin. Pharmacokinet. 42 (4), 327–360. [PubMed: 12648025]

Guide to Community Preventive Services. CPSTF Findings for Excessive Alcohol Consumption. 〈https://www.thecommunityguide.org/content/task-force-findings-excessive-alcohol-consumption〉. Accessed 29 March 2021.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Hall W, Degenhardt L, 2009. Adverse health effects of non-medical cannabis use. Lancet 374 (9698), 1383–1391. [PubMed: 19837255]

Hall W, Lynskey M, 2016. Evaluating the public health impacts of legalizing recreational cannabis use in the United States. Addiction 111 (10), 1764–1773. [PubMed: 27082374]

Hartman RL, Brown TL, Milavetz G, Spurgin A, Pierce RS, Gorelick DA, Gaffney G, Huestis MA, 2015. Cannabis effects on driving lateral control with and without alcohol. Drug Alcohol Depend. 154, 25–37. [PubMed: 26144593]

Hasin DS, Sarvet AL, Cerdá M, Keyes KM, Stohl M, Galea S, Wall MM, 2017. US adult illicit cannabis use, cannabis use disorder, and medical marijuana laws: 1991–1992 to 2012–2013. JAMA Psychiatry 74 (6), 579–588. [PubMed: 28445557]

Heslin KC, Owens PL, Karaca Z, Barrett ML, Moore BJ, Elixhauser A, 2017. Trends in opioid-related inpatient stays shifted after the US transitioned to ICD-10-CM diagnosis coding in 2015. Med.Care 55 (11), 918–923. [PubMed: 28930890]

Hudak M, Severn D, Nordstrom K, 2015. Edible cannabis–induced psychosis: intoxication and beyond. Am. J. Psychiatry 172 (9), 911–912.

Ingram DD, Malec DJ, Makuc DM, Kruszon-Moran D, Gindi RM, Albert M, Beresovsky V, Hamilton BE, Holmes J, Schiller JS, 2018. National Center for Health Statistics guidelines for analysis of trends, in: Statistics A.o.T.N.C.f.H. (Ed.) 179 ed.

Johnston LD, Miech RA, O'Malley PM, Bachman JG, Schulenberg JE, Patrick ME, 2021. Monitoring the Future National Survey Results on Drug Use, 1975–2020: Overview, Key Findings on Adolescent Drug Use. Institute for Social Research.

King BA, Jones CM, Baldwin GT, Briss PA, 2020. The EVALI and youth vaping epidemics—implications for public health. New Engl. J. Med. 382 (8), 689–691. [PubMed: 31951683]

Kosterman R, Bailey JA, Guttmannova K, Jones TM, Eisenberg N, Hill KG, Hawkins JD, 2016. Marijuana legalization and parents' attitudes, use, and parenting in Washington State. J. Adolesc. Health 59 (4), 450–456. [PubMed: 27523977]

Kumar N, Puljević C, Ferris J, Winstock A, Barratt MJ, 2019. Cannabis use patterns at the dawn of US cannabis reform. J. Cannabis Res. 1 (1), 1–6. [PubMed: 33526052]

Levine A, Clemenza K, Rynn M, Lieberman J, 2017. Evidence for the risks and consequences of adolescent cannabis exposure. J. Am. Acad. Child Adolesc. Psychiatry 56 (3), 214–225. [PubMed: 28219487]

Loflin M, Earleywine M, 2014. A new method of cannabis ingestion: the dangers of dabs? Addict. Behav. 39 (10), 1430–1433. [PubMed: 24930049]

Marx GE, Chen Y, Askenazi M, Albanese BA, 2019. Syndromic surveillance of emergency department visits for acute adverse effects of marijuana, tri-county health department, Colorado, 2016–2017. Public Health Rep. 134 (2), 132–140. [PubMed: 30721641]

Maxwell CJ, Jesdale BM, Lapane KL, 2021. Recent trends in cannabis use in older Americans. Ann. Intern. Med. 174 (1), 133–135. [PubMed: 32866420]

McDonagh MS, Selph SS, Buckley DI, Holmes RS, Mauer K, Ramirez S, Hsu FC, Dana T, Fu R, Chou R, 2020. Nonopioid Pharmacologic Treatments for Chronic Pain [Internet]. Rockville, MD: Agency for Healthcare Research and Quality (US); 2020 Apr. (Comparative Effectiveness Review, No. 228.) Available from: 〈https://www.ncbi.nlm.nih.gov/books/NBK556277/〉.

Meier MH, Caspi A, Ambler A, Harrington H, Houts R, Keefe RS, McDonald K, Ward A, Poulton R, Moffitt TE, 2012. Persistent cannabis users show neuropsychological decline from childhood to midlife. Proc. Natl. Acad. Sci. 109 (40), E2657–E2664. [PubMed: 22927402]

Miech RA, Patrick ME, O'Malley PM, Johnston LD, Bachman JG, 2020. Trends in reported marijuana vaping among US adolescents, 2017–2019. JAMA 323 (5), 475–476. [PubMed: 31848566]

Morrison C, Smith K, Gruenewald PJ, Ponicki WR, Lee JP, Cameron P, 2016. Relating off-premises alcohol outlet density to intentional and unintentional injuries. Addiction 111 (1), 56–64. [PubMed: 26283189]

NIDA, 2019. Is Marijuana Addictive? 〈https://www.drugabuse.gov/publications/research-reports/marijuana/marijuana-addictive〉.

National Concil of State Legislatures. State Medical Marijuana Laws 2020 [updated August 23, 2021. Available from: 〈https://www.ncsl.org/research/health/state-medical-marijuana-laws.aspx〉.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

NEDS Database Documentation. Healthcare Cost and Utilization Project (HCUP) Rockville, MD [updated April 27, 3030. Available from: https://www.hcup-us.ahrq.gov/db/nation/neds/nedsdbdocumentation.jsp.

O'malley KJ, Cook KF, Price MD, Wildes KR, Hurdle JF, Ashton CM, 2005. Measuring diagnoses: ICD code accuracy. Health Serv. Res 40 (5p2), 1620–1639. [PubMed: 16178999]

Patrick ME, Miech RA, Kloska DD, Wagner AC, Johnston LD, 2020. Trends in marijuana vaping and edible consumption from 2015 to 2018 among adolescents in the US. JAMA Pediatr. 174 (9), 900–902. [PubMed: 32250422]

Raber JC, Elzinga S, Kaplan C, 2015. Understanding dabs: contamination concerns of cannabis concentrates and cannabinoid transfer during the act of dabbing. J. Toxicol. Sci. 40 (6), 797–803. [PubMed: 26558460]

Ramaekers JG, Berghaus G, van Laar M, Drummer OH, 2009. Dose Related Risk of Motor Vehicle Crashes after Cannabis Use: an Update, Drugs, Driving and Traffic Safety. Springer, pp. 477–499.

Rog DJ, Nurmikko TJ, Friede T, Young CA, 2005. Randomized, controlled trial of cannabis-based medicine in central pain in multiple sclerosis. Neurology 65 (6), 812–819. [PubMed: 16186518]

Salloum NC, Krauss MJ, Agrawal A, Bierut LJ, Grucza RA, 2018. A reciprocal effects analysis of cannabis use and perceptions of risk. Addiction 113 (6), 1077–1085. [PubMed: 29377544]

Schoeler T, Petros N, Di Forti M, Klamerus E, Foglia E, Ajnakina O, Gayer-Anderson C, Colizzi M, Quattrone D, Behlke I, 2016. Effects of continuation, frequency, and type of cannabis use on relapse in the first 2 years after onset of psychosis: an observational study. Lancet Psychiatry 3 (10), 947–953. [PubMed: 27567467]

Shen JJ, Shan G, Kim PC, Yoo JW, Dodge-Francis C, Lee Y-J, 2019. Trends and related factors of cannabis-associated emergency department visits in the United States: 2006–2014. J. Addict. Med. 13 (3), 193–200. [PubMed: 30418337]

Shi Y, 2017. Medical marijuana policies and hospitalizations related to marijuana and opioid pain reliever. Drug Alcohol Depend. 173, 144–150. [PubMed: 28259087]

Silins E, Horwood LJ, Patton GC, Fergusson DM, Olsson CA, Hutchinson DM, Spry E, Toumbourou JW, Degenhardt L, Swift W, 2014. Young adult sequelae of adolescent cannabis use: an integrative analysis. Lancet Psychiatry 1 (4), 286–293. [PubMed: 26360862]

Smart R, Caulkins JP, Kilmer B, Davenport S, Midgette G, 2017. Variation in cannabis potency and prices in a newly legal market: evidence from 30 million cannabis sales in Washington state. Addiction 112 (12), 2167–2177. [PubMed: 28556310]

Substance Abuse and Mental Health Services Administration, 2019. Key substance use and mental health indicators in the United States: Results from the 2018 National Survey on Drug Use and Health, in: Administration SAMHS. (Ed.). Center for Behavioral Health Statistics and Quality, Rockville, MD.

Substance Abuse and Mental Health Services Administration, 2020. Key substance use and mental health indicators in the United States: Results from the 2019 National Survey on Drug Use and Health in: Center for Behavioral Health Statistics and Quality, S.A.a.M.H.S.A. (Ed.). Rockville, MD.

Thomas AA, Von Derau K, Bradford MC, Moser E, Garrard A, Mazor S, 2019. Unintentional pediatric marijuana exposures prior to and after legalization and commercial availability of recreational marijuana in Washington state. J. Emerg. Med. 56 (4), 398–404. [PubMed: 30846215]

Tremblay M, Baydala L, Khan M, Currie C, Morley K, Burkholder C, Davidson R, Stillar A, 2020. Primary substance use prevention programs for children and youth: a systematic review. Pediatrics 146 (3).

Volkow ND, Baler RD, Compton WM, Weiss SR, 2014. Adverse health effects of marijuana use. N. Engl. J. Med. 370 (23), 2219–2227. [PubMed: 24897085]

Wang GS, Davies SD, Halmo LS, Sass A, Mistry RD, 2018. Impact of marijuana legalization in Colorado on adolescent emergency and urgent care visits. J. Adolesc. Health 63 (2), 239–241. [PubMed: 29609916]

Wang GS, Roosevelt G, Le Lait M-C, Martinez EM, Bucher-Bartelson B, Bronstein AC, Heard K, 2014. Association of unintentional pediatric exposures with decriminalization of marijuana in the United States. Ann. Emerg. Med. 63 (6), 684–689. [PubMed: 24507243]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Ware MA, Daeninck P, Maida V, 2008. A review of nabilone in the treatment of chemotherapy-induced nausea and vomiting. Ther. Clin. risk Manag. 4 (1), 99–107. [PubMed: 18728826]

Whitehill JM, Harrington C, Lang CJ, Chary M, Bhutta WA, Burns MM, 2019. Incidence of pediatric cannabis exposure among children and teenagers aged 0 to 19 years before and after medical marijuana legalization in Massachusetts. JAMA Netw. Open 2 (8), e199456. –e199456. [PubMed: 31418807]

Yang H, Pasalic E, Rock P, Davis JW, Nechuta S, Zhang Y, 2021. Interrupted time series analysis to evaluate the performance of drug overdose morbidity indicators shows discontinuities across the ICD-9-CM to ICD-10-CM transition. Inj. Prev. 27 (Suppl 1), i35–i41. [PubMed: 33674331]

Zajicek JP, Hobart JC, Slade A, Barnes D, Mattison PG, Group MR, 2012. Multiple sclerosis and extract of cannabis: results of the MUSEC trial. J. Neurol., Neurosurg. Psychiatry 83 (11), 1125–1132. [PubMed: 22791906]

Zalesky A, Solowij N, Yücel M, Lubman DI, Takagi M, Harding IH, Lorenzetti V, Wang R, Searle K, Pantelis C, 2012. Effect of long-term cannabis use on axonal fibre connectivity. Brain 135 (7), 2245–2255. [PubMed: 22669080]

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Three-question summary box:

1. Question: What is the current understanding of this subject? Answer: Over the past decade, many states are legalizing nonmedical adult use of cannabis, products are changing, and attitudes toward cannabis are shifting, yet there is still much to be learned about how this affects health.
2. Question: What does this report add to the literature? Answer: This report provides most recent available data on cannabis-associated emergency department visits, and highlight segments of the population at greatest risk.
3. Question: What are the implications for public health practice? Answer: Targeted interventions are needed to protect vulnerable populations from cannabis-associated harm. Increased efforts are needed by pediatricians, social workers, epidemiologists, and other preventionists in response to the changing cannabis landscape in the U.S.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

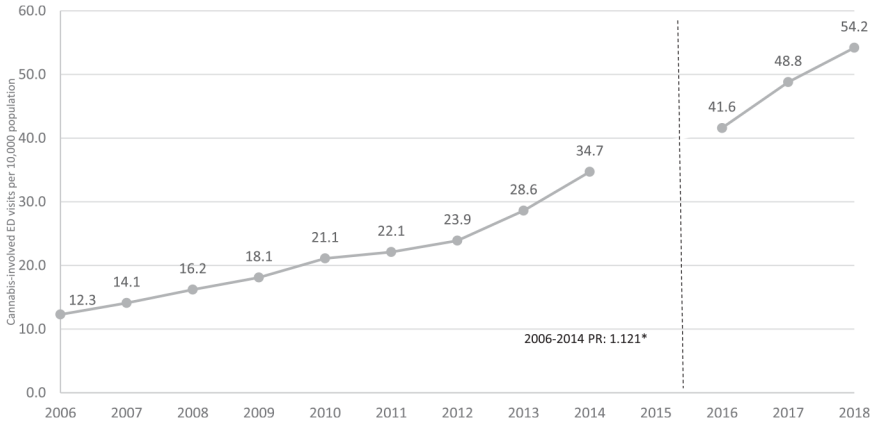

Fig. 1.

Age-adjusted rates of cannabis-associated emergency department visits per 100,000 population, 2006–2018, United States. Abbreviations: PR: prevalence ratio. Dashed vertical line represents the change from ICD-9 to ICD-10 coding in October 2015. The prevalence ratio for a 1-year increase in year from 2006 to 2014 was 1.121 (95% CI: 1.120, 1.122), indicating a 12.1% increase in the rate of cannabis-related ED visits per year. Because of the shift from ICD-9-CM to ICD-10-CM in the fourth quarter of 2015, we only examined the trend from 2006 through 2014 and did not include the year 2015 in the trend analysis. From 2016–2017, the rate of cannabis-associated ED visits increased 17.3% ($p < 0.05$). The rate increased 11.1% from 2017 to 2018 ($p < 0.05$).

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Drug Alcohol Depend. Author manuscript; available in PMC 2023 January 30.

Table 1

Differences in rates of cannabis-associated emergency department visits per 10,000 population, 2017–2018, United States.

	2017		2018			
Visit characteristic	**n**	**Rate (SE)**	**n**	**Rate (SE)**	**Absolute change in rate**	**Relative % change in rate**
All	1555,164	48.8 (0.4)	1732,605	54.2 (0.4)	**5.4**	**11.1**
Sex						
Male	980,466	61.2 (0.6)	1068,019	66.5 (0.7)	**5.3**	**8.7**
Female	574,631	36.5 (0.5)	664,477	42.3 (0.5)	**5.8**	**15.9**
Age group (years)						
0–14	14,321	2.3 (0.2)	16,471	2.7 (0.2)	**0.4**	**17.4**
15–19	159,657	75.6 (1.9)	167,862	79.6 (1.9)	4.0	5.3
20–24	243,860	110.3 (2.2)	260,816	119.2 (2.3)	8.9	8.1
25–34	429,353	94.7 (1.4)	473,686	103.7 (1.5)	**9.0**	**9.5**
35–44	277,949	68.0 (1.3)	319,264	77.3 (1.4)	**9.3**	**13.7**
45–54	221,277	52.2 (1.1)	240,970	57.9 (1.2)	**5.7**	**10.9**
55–64	155,387	37.0 (0.9)	185,028	43.8 (1.0)	**6.8**	**18.4**
> 65	53,360	10.5 (0.5)	68,509	13.1 (0.5)	**2.6**	**24.8**
Census region [a]						
Northeast	279,452	50.9 (1.0)	302,309	55.6 (1.0)	**4.7**	**9.2**
Midwest	316,306	48.4 (0.9)	434,223	66.2 (1.0)	**17.8**	**36.8**
South	582,064	48.5 (0.6)	613,705	50.7 (0.7)	**2.2**	**4.5**
West	377,352	48.4 (0.8)	382,369	48.7 (0.8)	0.3	0.6
County urbanization level [b]						
Large central metro	578,098	56.3 (0.7)	605,488	58.9 (0.8)	**2.6**	**4.6**
Large fringe metro	251,442	32.2 (0.6)	304,706	38.9 (0.7)	**6.7**	**20.8**
Medium metro	340,985	51.8 (0.9)	369,967	55.8 (0.9)	**4.0**	**7.7**
Small metro	150,310	52.6 (1.4)	196,921	68.6 (1.6)	**16.0**	**30.4**
Micropolitan (nonmetro)	138,876	54.7 (1.5)	147,647	58.1 (1.5)	3.4	6.2
Noncore (nonmetro)	69,047	42.0 (1.6)	75,368	45.0 (1.7)	3.0	7.1
Admitted to hospital						

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Visit characteristic		2017 n	2017 Rate (SE)	2018 n	2018 Rate (SE)	Absolute change in rate	Relative % change in rate
	Yes	622,817	19.2 (0.2)	645,671	19.8 (0.3)	**0.6**	**3.1**
	No	929,962	29.5 (0.3)	1085,338	34.3 (0.3)	**4.8**	**16.2**

Abbreviations: SE, Standard error

Note: Relative % change in rate was calculated by subtracting the 2017 rate from the 2018 rate and dividing by the 2017 rate. Rates were compared using z-scores.

Bold indicates statistical significance of $p < 0.05$.

[a] Census region of hospital as defined by the U.S. Census Bureau.

[b] Determined based on NCHS 2013 Urban-Rural classification scheme (https://www.cdc.gov/nchs/data/series/sr_02/sr02_166.pdf).