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Cannabis positivity rates in 17 emergency departments across the United States with varying degrees of marijuana legalization

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Abstract

Background: Many states in the United States have progressed towards legalization of marijuana including decriminalization, medicinal and/or recreational use. We studied the impact of legalization on cannabis-related emergency department visits in states with varying degrees of legalization.

Methods: Seventeen healthcare institutions in fifteen states (California, Colorado, Connecticut, Florida, Iowa, Kentucky, Maryland, Massachusetts, Missouri, New Hampshire, Oregon, South Carolina, Tennessee, Texas, Washington) participated. Cannabinoid immunoassay results and cannabis-related International Classification of Diseases (ninth and tenth versions) codes were obtained for emergency department visits over a 3- to 8-year period during various stages of legalization: no state laws, decriminalized, medical approval before dispensaries, medical dispensaries available, recreational approval before dispensaries and recreational dispensaries available. Trends and monthly rates of cannabinoid immunoassay and cannabis-related International Classification of Diseases code positivity were determined during these legalization periods.

Results: For most states, there was a significant increase in both cannabinoid immunoassay and International Classification of Diseases code positivity as legalization progressed; however, positivity rates differed. The availability of dispensaries may impact positivity in states with medical and/or recreational approval. In most states with no laws, there was a significant but smaller increase in cannabinoid immunoassay positivity rates.

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Conclusions: States may experience an increase in cannabis-related emergency department visits with progression toward marijuana legalization. The differences between states, including those in which no impact was seen, are likely multifactorial and include cultural norms, attitudes of local law enforcement, differing patient populations, legalization in surrounding states, availability of dispensaries, various ordering protocols in the emergency department, and the prevalence of non-regulated cannabis products.

Keywords

Marijuana; cannabis; Tetrahydrocannabinol; urine drug screen; ICD codes; legalization; decriminalization; recreational use

Introduction

Nearly 2.5% of the world's population consumes cannabis and its associated compounds [1]. Further, in the United States (US) in 2014, over 22 million adults and adolescents reported current use of cannabis. The main psychoactive ingredient in cannabis is Δ9-tetrahydrocannabinol (THC) which acts through the endocannabinoid system to affect symptoms like pain, nausea, and anorexia [1]. Cannabis, due to the reported benefits and low incidence of side effects, has been legalized for medical use in 37 US states as of August 2022 [2–4]. Further, 18 of the 37 states have also legalized cannabis for recreational use [3]. Despite ongoing legalization in most states, the federal government and the US Drug Enforcement Agency (DEA) continue to categorize marijuana as a schedule I drug [5].

Previous studies performed in the emergency department (ED) setting report variable impact of legalization status on cannabis use [1,6–15]. Interpretation of the findings is further complicated by the different definitions of cannabis use which could be a positive urine drug screen for THC, self-reported marijuana use, and/or positive International Classification of Diseases (ninth version) (ICD-9) or International Classification of Diseases (tenth version) (ICD-10) cannabis-related codes depending on the study. Most studies utilize and/or recommend monitoring positivity rates of urine drug screens as it provides higher volume objective data as compared to ICD codes [1,6,10,14]. The impact of dispensaries on cannabis use has also been studied [6,16–21]. Levine et al. [6] reported an increase in cannabis use after legalization in Arizona but no further increases after the opening of medical dispensaries, suggesting that legalization not the availability of dispensaries was associated with increased use. Mair et al. [17] showed only a transient increase in hospitalizations for cannabis use disorder in California with increasing medical dispensaries. However, other studies have shown that availability and proximity of dispensaries is associated with an increase in cannabis use and hospitalizations [16,19–22].

The clinical impact, if any, of an increase in cannabis-related ED visits should be considered [1,6,8–10,23]. Several studies have shown higher rates of traumatic injuries, mental health diagnoses, seizures, and burn injuries in ED patients using cannabis [1,6,8,9,12]. The incidence of cyclical vomiting and cannabis-induced hyperemesis has also increased [8]. These findings suggest that ED and laboratory resources, as well as consult services such as psychiatry, neurology, trauma, and medical toxicology may be impacted.

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The primary purpose of this study was to determine the trends in positivity rates for THC immunoassay and cannabis-related ICD-9 or ICD-10 codes at representative sites across fifteen states in the US with varying degrees of marijuana legalization.

Materials and methods

Study design and participating sites

Positivity rates for THC immunoassay ordered in the ED were determined per marijuana legalization period(s) at 17 sites in 15 states across the US In addition, we obtained the cannabis-related ICD codes associated with the ED visit for which a THC immunoassay was ordered. The following sites representing 15 different states participated in the study: University of Southern California and University of California San Francisco in California, University of Colorado Anschutz in Colorado, Yale University in Connecticut, University of Florida Jacksonville in Florida, University of Iowa in Iowa, University of Kentucky in Kentucky, Brigham, and Women's Hospital and Massachusetts General Hospital in Massachusetts, Johns Hopkins University in Maryland, Washington University in Missouri, Dartmouth Hitchcock Medical Center in New Hampshire, Providence Regional Laboratory in Oregon, The Medical University of South Carolina in South Carolina, Vanderbilt University in Tennessee, University of Texas Medical Branch at Galveston in Texas, and University of Washington in Washington. The participating states and/or sites, dates and phases of legalization, date ranges, and data collected (including volumes) are shown in Figure 1(a) and Supplemental Table 1a. Additional characteristics including type, location, and size of the institution of each site are shown in Supplemental Table 1b.

This study was approved by the Mass General Brigham Health System Institutional Review Board as a multisite study on which all participating states and sites were listed.

Data collection

All ED patients (adult, pediatric, or both, depending on the patient population at each site) for which a THC immunoassay (detecting Δ9-carboxy-tetrahydrocannabinol) or urine drug screen immunoassay panel including a THC immunoassay was ordered during an ED visit in the date ranges shown in Figure 1(a) and Supplemental Table 1a were included. During the time of the study, the site in Iowa and at University of Southern California in California, THC immunoassay was only orderable individually, not as part of the urine drug screen panel. At all other sites, the urine drug screen panel includes THC immunoassay, which was ordered per site-specific protocols. Testing was otherwise ordered at the discretion of the clinical care team.

Results of the THC immunoassay (performed in the laboratory servicing the ED) and, if available, cannabis-related ICD-9 and ICD-10 codes associated with the ED visit were obtained from the laboratory information system and electronic health record, respectively. Point of care THC immunoassay results were not included in the study. When available, legal sex (henceforth referred to as sex as most electronic healthcare systems use legal sex) and age were also obtained. Depending on the site, a structured query language (SQL), R programming, or a commercial software tool (e.g., Performance Insight) was utilized to

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extract the retrospective data from the institution's laboratory information system and/or electronic health record. The date ranges varied from 2010–2019 to 2015–2019 depending on the availability of data at each site. To avoid any bias of the COVID-19 pandemic, data after 12/31/2019 was excluded.

Qualitative urine THC immunoassays, which detect the carboxy metabolite, was performed on various automated clinical chemistry analyzers using different methodologies. All sites used a cutoff of 50 ng/mL except for Massachusetts General Hospital which used a cutoff of 20 lg/L and Dartmouth Hitchcock Medical Center which switched from the cutoff of 50 lg/L to 20 lg/L when the site transitioned from having medical dispensaries available to both being decriminalized and having medical dispensaries available.

All ICD code(s) associated with the ED visit (e.g., encounter, admission, and/or discharge diagnosis) were included. ICD codes unrelated to the ED visit, including those from the problem list, were excluded. Supplemental Table 2 lists the ICD codes that were considered positive for cannabis-related use [66]. Cases with the following cannabis-related ICD-9 codes were not categorized as positive: 305.23 (Cannabis abuse, in remission), 304.33 (Cannabis dependence, in remission). Cases with the following cannabis-related ICD-10 codes were not categorized as positive: F12.11 (Cannabis abuse, in remission), F12.21 (Cannabis dependence, in remission), T40.7X6A, T40.7X6D, T40.7X6S (codes associated with under-dosing of Cannabis), R11.15 (cyclical vomiting syndrome unrelated to migraine).

Legalization periods

Legalization periods as shown in Figure 1(a) and Supplemental Table 1a included: no state legislation decriminalizing marijuana or approving marijuana for medical or recreational use (shortened to 'no state laws' throughout), decriminalized, medical approval before dispensaries, medical dispensaries available, recreational approval before dispensaries and recreational dispensaries available [24–65]. The legalization status as of 12/31/2019 for the continental US and location of the participating site(s) within the states are shown in Figure 1(b).

Data analysis

Patient demographics (age and sex) were compared between legalization periods (e.g. D (decriminalized), DM (decriminalized and medical approval before dispensaries)) using the Pearson's chi-squared (χ^2) test for categorical outcomes, and the Wilcoxon rank-sum test for non-normally distributed continuous variables. A *P*-value of ≤0.05 is defined as significant.

The median, and 25th and 75th percentiles for the THC immunoassay and ICD codes positivity rates per month were calculated for each legalization period at each site. For Missouri only the year (between 2013–2015) and the associated legalization period, not the exact date, was made available so monthly averages could not be calculated in 2013, 2014 or 2015.

Logistic regression with overall positivity as the dependent variable and time periods as a categorical predictor were used to assess trends in THC immunoassay positivity or ICD

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codes over legalization periods in states with three or more legalization periods. The analysis was adjusted for sex and age. The significance of a linear trend was tested by examining contrasts of marginal linear predictions with a post-estimation command. Further, the trend analysis for both the THC immunoassay and ICD-10 codes positivity was stratified by sex and age groups (<18, 19–29, 30–39, 40–49, 50–59, >59 years). For states with at least two legalization periods, difference in percent positivity from previous legalization period was also assessed using the Pearson's chi-squared (χ^2) test. For states with no state laws, trends in positivity by calendar year were determined.

Based on the sample size of this investigation, the minimum percentage increase in the dichotomous outcomes that could be detected as statistically significant, in any comparison, was 5%, assuming a power of 0.80 and an alpha level of 5%.

Statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC) & STATA version SE15 (StataCorp. 2015. *Stata Statistical Software: Release 14*. College Station, TX: StataCorp LP). Data analysis and visualization were performed using Python 3.6 (Python Software Foundation, Beaverton, OR, USA) and pandas v1.4.3, seaborn v0.11, matplotlib v3.5.2 packages, and Tableau v2022.1 (Tableau Software, Seattle, WA, USA), where datasets were managed on a local MySQL community server v8.0.29 (Oracle, Austin, TX, USA) database instance and Apache Superset v2.0 (Apache Software Foundation, Wakefield, MA, USA).

Results

Urine cannabinoid immunoassay screen analysis

Patient demographics (percentage male, median age (interquartile range (IQR)) per site, and legalization period are shown in Supplemental Table 3. There were significant differences between legalization periods at most sites, therefore statistical analyses adjusted for sex and age.

The THC immunoassay positivity rates within the same legalization period were significantly different between the sites (Figure 2, $P < 0.0001$ for all legalization periods but $P = 0.007$ for sites with medical dispensaries available). There was a significant upward trend ($P < 0.0001$) for all states as legalization progressed. The average positivity rates fluctuated as legalization progressed but ranged from 20.5% at sites in the decriminalized and medical approval before dispensaries legalization period to 32.7% at sites in the decriminalized and medical and recreational dispensaries available legalization period. Furthermore, the positivity rates were notably higher at some sites including Missouri, New Hampshire, Oregon, Colorado, and Washington which all surpassed 30% in one or more legalization periods.

There was an increasing trend in the percentage of positive THC immunoassay results as legalization progressed at most sites (Colorado ($P < 0.0001$), Oregon ($P = 0.008$), Washington ($P < 0.0001$), Massachusetts ($P < 0.0001$), New Hampshire ($P = 0.0002$), Missouri ($P < 0.0001$)) (Figure 3(a)). However, the trend was not significant in either California ($P = 0.3503$) or Maryland ($P = 0.4138$). In Connecticut and Florida there were

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only two legalization periods during the study, so trend analysis was not performed. In Connecticut there was a significant increase from 19.9% in the decriminalized and medical approval prior to dispensaries legalization period to 24.0% in the decriminalized and medical dispensaries available legalization period ($P < 0.0001$). However, in Florida the increase from 23.4% in no state laws to 24.0% in medical dispensaries available was not significant ($P = 0.406$). Supplemental Table 4 provides the *P*-values for changes from the previous legalization period in states with two or more legalization periods. The increasing rates of THC immunoassay positivity were similar among the different sexes and age groups (<18, 18–29, 30–39, 40–49, 50–59, >59 years).

The changes in THC immunoassay percent positivity between the legalization periods are shown in Table 1a as well as the cumulative increases, average change for each transition, cumulative average (5.5%), and weighted average change per transition (2.7%). At some sites (e.g., Colorado, Oregon, Washington, Massachusetts, Connecticut) a greater increase in positivity occurred with the availability of dispensaries.

At sites with no progression towards legalization (e.g. no state laws) during the study period (Iowa, Kentucky, South Carolina, Tennessee, and Texas), results were variable (Figure 3(b)). There was a significant upward trend in THC immunoassy positivity in South Carolina ($P < 0.0001$) and Tennessee ($P = 0.0112$). However, the only significant change from the previous year was between 2015 to 2016 in Tennessee ($P = 0.018$). In Kentucky and Texas, the overall trend was not significant but significant increases were seen between 2018 to 2019 ($P = 0.024$) in Kentucky and 2017 to 2018 ($P = 0.024$) and 2018 to 2019 ($P = 0.002$) in Texas. In Iowa, there was neither a significant trend nor a significant change between each sequential year. Despite the significant increases in most of the states with no laws, the change in percent positivity was not as striking as in those states who progressed towards legalization (Table 1b). The cumulative average change was 1.0% and the yearly average change was 0.4%.

When examining the sites within California and Massachusetts, we found that neither University of Southern California ($P = 0.6775$) nor University of California San Francisco ($P = 0.8608$) had an increasing trend in THC immunoassay positivity, but rates were higher at University of Southern California than University of California San Francisco (39% vs 24%). Both Brigham and Women's Hospital and Massachusetts General Hospital had increasing trends in THC immunoassay with Massachusetts General Hospital having slightly higher positivity rates [14].

Cannabis-related ICD-9 and ICD-10 code analysis

The ICD code positivity rates within the same legalization period were significantly different between the sites (Figure 4, $P < 0.0001$ for all legalization periods). There was also a significant upward trend ($P < 0.0001$) for all states as legalization progressed. However, the average positivity rates fluctuated as legalization progressed and ranged from 0.5% at sites in the decriminalized and medical approval before dispensaries legalization period to 6.4% at sites in the decriminalized and medical and recreational dispensaries available legalization period, like THC immunoassay results. However, the positivity rates were notably higher for three sites: Texas, New Hampshire and Colorado, which all surpassed 7% in one or

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more legalization period and primarily drove the increasing trend in percent positivity with legalization progression.

There was an increasing trend in ICD code positivity as legalization progressed at most sites (Colorado ($P < 0.0001$), Oregon ($P < 0.0001$), Massachusetts ($P = 0.0204$), New Hampshire ($P < 0.0001$)) (Figure 5). However, the trend was not significant in California ($P = 0.3001$). In Connecticut, Maryland, and Florida there were only two legalization periods during the study, so trend analysis was not performed. In Connecticut there was a significant increase from 1.2% in the decriminalized and medical approval before dispensaries legalization period to 3.6% in the decriminalized and medical dispensaries available legalization period ($P < 0.0001$); however, in Florida the percentage remained 0.1% ($P = 0.862$) and in Maryland the increase from 0.3% in the decriminalized and medical approval before dispensaries legalization period to 0.4% in the decriminalized and medical dispensaries available legalization period was not significant ($P = 0.241$) (Figure 5, Supplemental Table 5). Supplemental Table 5 provides the *P*-values for changes from the previous legalization period in states with two or more legalization periods. Washington only had ICD code data for the decriminalized and medical and recreational dispensaries available legalization period. The increasing rates of ICD code positivity were similar among the different sexes and age groups (<18, 18–29, 30–39, 40–49, 50–59, >59 years).

Discussion

We report an increase in positivity in both THC immunoassay and cannabis-related ICD codes in the ED at most sites in the US states we studied as legalization has progressed with the exceptions of Florida, Maryland, and both sites in California. The positivity rates for THC immunoassay and ICD codes differed significantly between sites within the same legalization period(s). Overall positivity rates, however, increased by an average of 2.7% per transition for THC immunoassay and 1.0% for ICD codes across all sites. To our knowledge, this is the first and longest-duration nationwide study to determine THC immunoassay and ICD code positivity rates across 17 sites in 15 states, including states with no marijuana legalization and states with data before and after the opening of dispensaries.

The explanation for the different trends as legalization progressed as well as the higher positivity rates for THC immunoassay and ICD codes in certain states is likely multi-factorial. Factors include different cultural norms and attitudes towards drug use, patient populations at each site, responses of local law enforcement, availability and proximity of dispensaries, availability of non-regulated THC products, legalization in surrounding states, different regulations or opinions at the county vs. state level, and/or ordering protocols for urine drug screens. Interestingly, none of the changes were specific to certain sexes or age groups at any of the sites; increasing positivity, or lack thereof, was similar in males and females and in all age groups (e.g., <18, 18–29, 30–39, 40–49, 50–59, >59 years).

Most states (Colorado, Connecticut, Massachusetts, Missouri, Oregon, Washington) had an increasing trend in positivity with legalization. One driver is likely the availability of medical and/or recreational dispensaries, particularly in Colorado, Connecticut, Massachusetts, Oregon, and Washington where percentage increases are higher with the

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opening of dispensaries. Currently, there exists a wide geographic variation ranging from 30 to 220 dispensaries within a 10-mile radius of sites in Colorado, Massachusetts, Oregon, and Washington, with Connecticut only having four dispensaries within a 10-mile radius of New Haven [67]. More liberal legalization in surrounding states can also elucidate increasing trends; Oregon is surrounded by three states with THC legalization and the site studied in Missouri is adjacent to Illinois which, as of 12/31/2019, is decriminalized, has medical dispensaries available and has recreational approval but no dispensaries available and quite progressive in THC legalization.

The THC immunoassay positivity rates were higher in Colorado, Missouri, Oregon, and Washington, surpassing 30%. Marijuana legalization in Colorado, Washington, and Oregon began in the 1970s, and progression to medical approval occurred long before the start of the study period. The long-standing approval and tolerant culture support the higher positivity rates. Further, the sites in Missouri and Washington service primarily urban populations with higher likelihood of cannabis use.

In three states/four sites (University of Southern California and University of California San Francisco in California, Florida, and Maryland) there was no significant increase in THC immunoassay positivity. The consistent and relatively high positivity rate (25%) across the legalization periods at both sites in California is likely due to cultural norms, the longstanding legalization and lack of stigma surrounding marijuana and the economic benefits of legal cannabis [68]. Further, in areas surrounding University of Southern California and University of California San Francisco arrest rates for marijuana-related crimes are relatively low and irrespective of legalization status. In contrast, in Maryland, despite voter support and ongoing legalization, arrest rates for marijuana have increased with the highest rates in Baltimore County [69]. Maryland also has one of the lowest thresholds for decriminalization (<10 grams) and law enforcement continues to arrest even below that threshold [70]. These factors support the steady 20% positivity rates in Maryland. At the University of Florida, Jacksonville, the patient population is primarily urban and underserved and we postulate that cannabis consumption amongst these groups is less likely to be impacted by legalization status and/or availability of dispensaries leading to unchanging positivity rates around 24% at this site.

The THC immunoassay results in New Hampshire are impacted by a lowering of the THC immunoassay cutoff from 50 lg/L to 20 lg/L as the state transitioned to the decriminalized and medical dispensaries available legalization period. It is difficult to know if there increase in positivity was due to decriminalization or primarily due to the change in cutoff. Further, there is a significant decrease in THC immunoassay positivity when medical dispensaries became available in New Hampshire that is associated with a significant increase in ICD positivity which may be due to changes in ordering practice and physician bias in cannabis-related ICD coding. The percentage of patients with a positive ICD code and negative THC immunoassay result in New Hampshire increased from 0.55% at in the medical approval before dispensaries legalization period to 2.07% in the medical dispensaries available legalization period and back to 0.67% in the decriminalized and medical dispensaries available legalization period with when the cutoff was changed.

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Our study included five states (Iowa, Kentucky, South Carolina, Tennessee, Texas) in which marijuana was not legalized during the study period. Positivity rates still increased in most of these states, but the percentage change was lower than in states that have progressed toward legalization. The slow increase may be due to the overall decreasing stigma associated with cannabis use across the US. In South Carolina, the availability of non-regulated THC products such as Δ8-THC at cannabidiol shops [71] may account for the increasing trend. In Nashville, there is local support for cannabis use but not state-wide support, which may explain the trend in positivity rates. Further, the significant increase from 2015 to 2016 in Tennessee may be associated with the legalization of cannabidiol.

The positivity rates for ICD codes were low, confirming findings from other studies [11,14], and ranged from 0.3% to 13.5% in all states in our study. The higher percentages in California, Colorado, New Hampshire, and Texas were likely due to more selective testing ordering in patients presenting to the ED with cannabis-related symptoms or toxicity and therefore higher likelihood of positivity. During the time of the study, the University of Southern California in California reinforced this ordering practice by not including THC on the urine drug screen panel; it had to be ordered separately. Further, as suggested by our ICD code data, the increasing THC immunoassay positivity rates in the ED with progressive legalization and opening of dispensaries may not directly correlate with an increase in THC-related encounters and/or THC intoxication. The ICD codes should theoretically be more reflective of acute THC intoxication or treatment for associated side effects. However, the subjectivity of ICD codes and relatively low percent positivity suggest that they may not be a reliable marker of the potential impact of marijuana legalization. THC immunoassay may be a better indicator of general cannabis use in patients presenting to the ED.

Emergency department operations and resources may be impacted by the steady increase in cannabis use associated with legalization. In addition, the potency of marijuana has increased dramatically over the past several decades which may lead to more acute intoxications and long-term side effects [72,73]. Δ9-Tetrahydrocannabinol variants and edible marijuana are also commonly ingested. States that have progressed towards legalization should be prepared to manage an increasing number of ED patients with cannabis-associated cyclical vomiting or hyperemesis, traumatic injuries, neuropsychiatric disorders, and burn injuries. Hospital admission rates as well as psychosocial services, neurological, trauma, and medical toxicology consults may also increase because of cannabis-related ED visits.

Limitations

This is an observational study and results are impacted by variability in clinician ordering of THC immunoassay and documentation of ICD-9 and ICD-10 codes as well as local and regional differences. Further, certain ICD codes (e.g., J66.2, cannabinosis) may not be specific to cannabis use. We chose representative sites within each state; however, site findings do not necessarily reflect the impact of legalization throughout the entire state. It was also challenging to determine the exact dates of legalization, but the dates were verified with at least two sources by a single person. We also uniformly considered THC >5% and any medical approval (e.g., terminally ill) as approved. Further, each site verified the dates of

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legalization in their state. We did not capture all transitions at each site because data could only be pulled back to a certain date in the laboratory information system; therefore, the trend analysis in Figure 2 does not represent the trend in the same states for each period. Our study spanned over several years and included the transition from ICD-9 to ICD-10 codes. The impact of this conversion and/or electronic health record utilized at each site is not known. In some states (Massachusetts, Maryland, Tennessee, Washington), ICD codes were not available for the entire time period for which we had THC immunoassay results, while in other states ICD codes were not provided. The THC immunoassay cutoff was lower at one site in Massachusetts (the Massachusetts General Hospital) and in the decriminalized with medical dispensaries available period in New Hampshire than all other sites. This may contribute to differences in positivity rates. Finally, at some sites repeat patients may have been included if they were not identifiable (e.g. needed a new medical record number on admission but were subsequently associated with an existing medical record number. The number of repeat patients is estimated to be <2% of all results.

Conclusions

In most states, the legalization of marijuana has led to an increase in cannabis use as indicated by both increasing THC immunoassay and ICD code positivity rates. To our knowledge, this is the first and longest-duration study to determine positivity rates in 15 different states and 17 different sites with various stages of marijuana legalization. While cannabis uses increased over time in states with no laws, the increases are smaller than those in states that have progressed towards legalization. The explanation for different trends and percentage positivity among the states is likely multi-factorial and includes different cultural norms and attitudes towards drug use, patient populations at the site, responses of local law enforcement, availability and proximity of dispensaries, availability of non-regulated THC products, legalization in surrounding states, different regulations or opinions at the county vs. state level, and/or ordering protocols for urine drug screen. As the results of our Massachusetts study [14] also suggested THC immunoassay positivity, an objective laboratory measure, should be used to monitor THC use and the impact of state-based progression in cannabis legalization. Further, it is important to monitor THC immunoassay positivity over several years and multiple legalization periods to accurately determine these dynamic trends and their impact on patients presenting to EDs with cannabis-related health issues.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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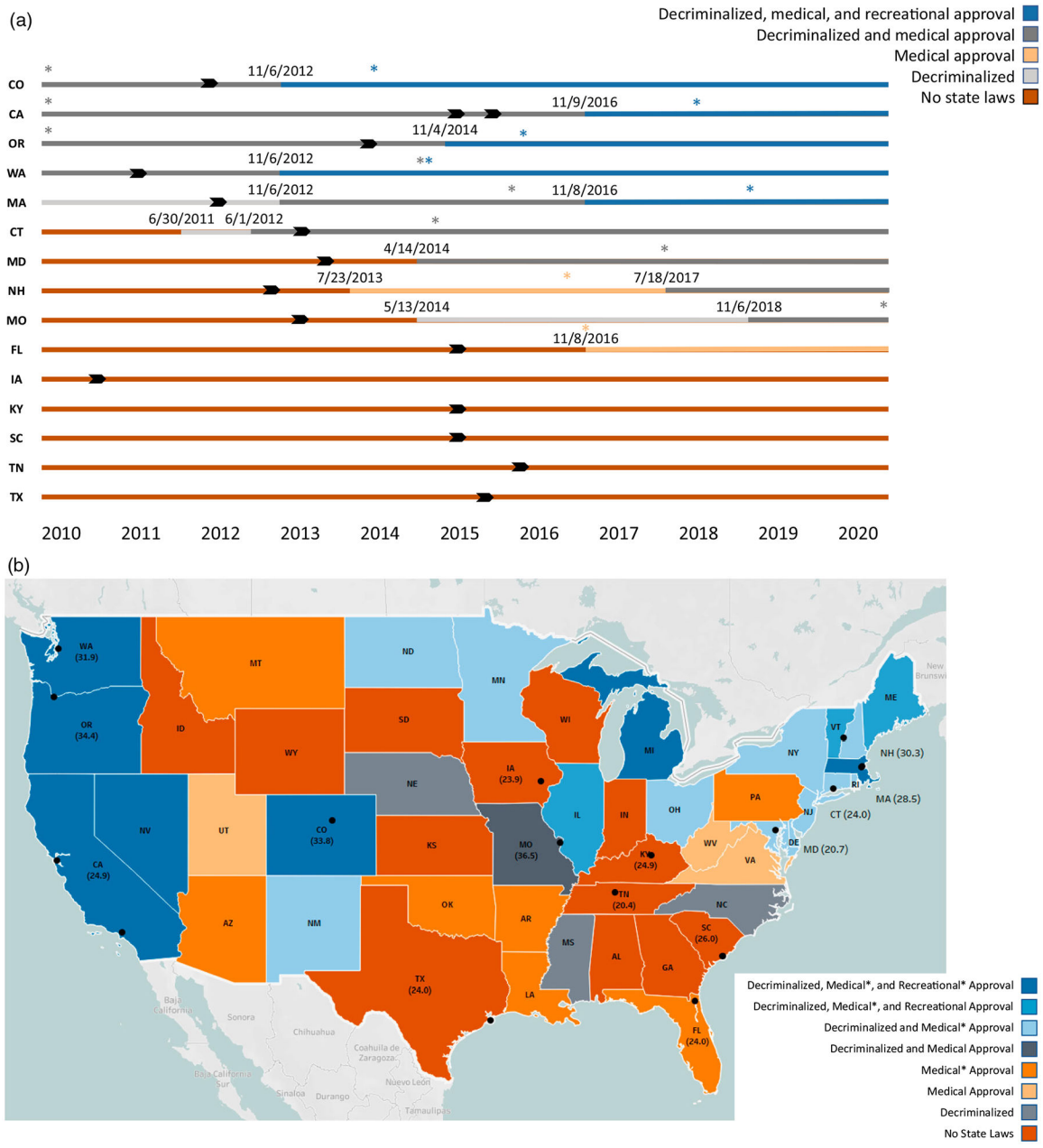

Figure 1.

(a) Nationwide emergency department Δ9-tetrahydrocannabinol study (THC). The participating states/sites and their legalization periods between 2010 and 2020 is shown. The dates of transition are displayed as well as the availability of dispensaries (*). ➧ Indicates the start of the data collection for each site; the start dates were the same for the two Massachusetts sites, but different for the two California sites. (b) Map of the United States and legalization status as of December 2019. The participating states have a black dot to indicate the location of the participating site within the state. The percent THC immunoassay positivity during the last legalization period for the participating states is also displayed in parentheses. The legalization period as of 12/31/19 in all continental

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US states is indicated. CO: Colorado; CA: California; OR: Oregon; WA: Washington; MA: Massachusetts; CT: Connecticut; MD: Maryland; NH: New Hampshire; MO: Missouri; FL: Florida; IA: Iowa; KY: Kentucky; SC: South Carolina; TN: Tennessee; TX: Texas.

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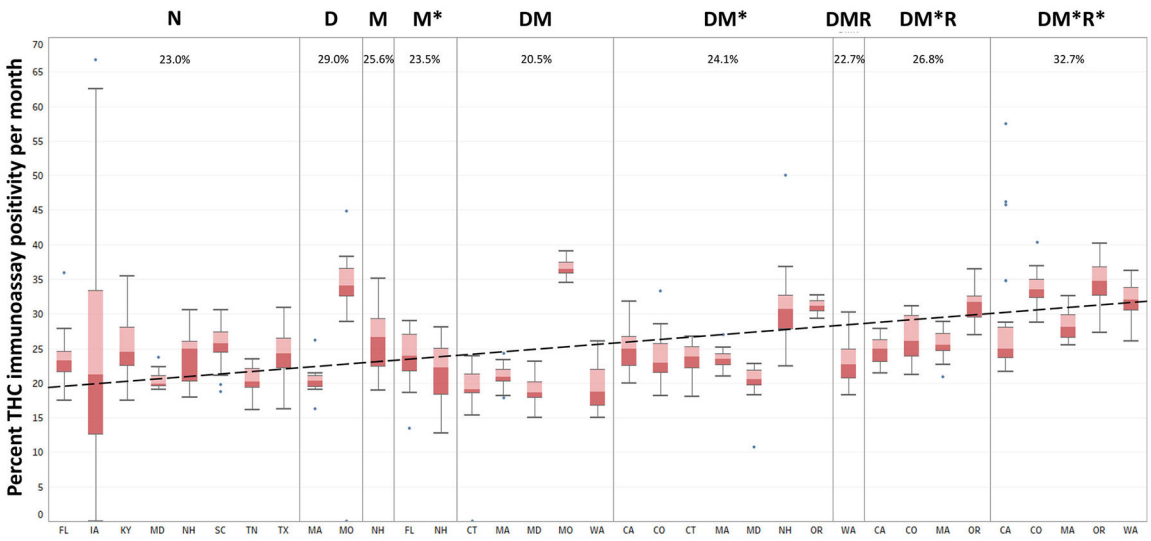

Figure 2.

Δ9-tetrahydrocannabinol (THC) immunoassay percent positivity across states by legalization period. The monthly THC immunoassay positivity for each legalization period and site with data in that period are shown. The median, 25th and 75th percentile for monthly THC IA positivity is plotted. N: No state laws; D: Decriminalized; M: Medical; R: Recreational, *Dispensary Available (M/R). The average percent positivity for each legalization period, combining the sites data, is shown within each box. The trend *P* value for changes in THC immunoassay positivity between legalizations periods for all states was <0.0001 and the associated trend line is displayed. The Person chi-square *P* value between states with similar legalization periods was <0.0001 for all legalization periods except for M* which had a *P* value of 0.007. CO: Colorado; CA: California; OR: Oregon; WA: Washington; MA: Massachusetts; CT: Connecticut; MD: Maryland; NH: New Hampshire; MO: Missouri; FL: Florida; IA: Iowa; KY: Kentucky; SC: South Carolina; TN: Tennessee; TX: Texas.

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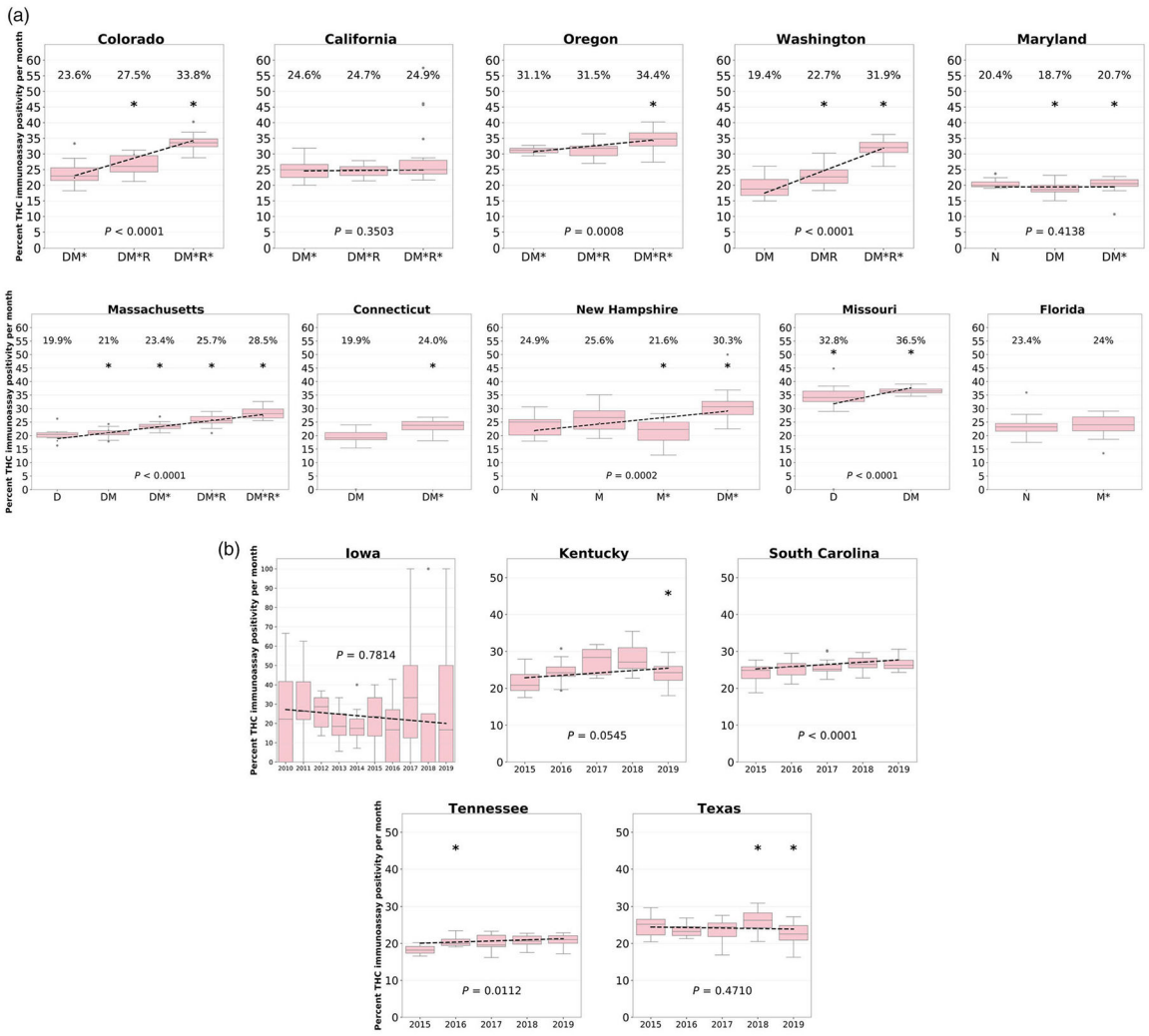

Figure 3.

(a) Average monthly D9-tetrahydrocannabinol (THC) immunoassay positivity rates per state per legalization period. Rates of monthly THC immunoassay positivity as legalization progressed at each site in the following states: Colorado, California, Oregon, Washington, Maryland, Massachusetts, Connecticut, New Hampshire, Missouri, Florida are shown. The median, 25th and 75th percentile for monthly THC immunoassay positivity is plotted. For Missouri only the year (between 2013 and 2015) and the associated legalization period, not the exact date, was available so monthly averages could not be calculated in 2013, 2014 or 2015. N: No state laws; D: Decriminalized; M: Medical; R: Recreational, Dispensary Available (M* ,R*). The trend *P* value for each site with three or more legalization periods (Colorado, California, Oregon, Washington, Maryland, Massachusetts, New Hampshire, Missouri) and associated trend lines are displayed. *indicates a significant difference from the previous legalization period and *P*-values are available in Supplemental Table 4. (b) Average monthly THC immunoassay positivity rates per year for states with no laws. Rates of monthly THC immunoassay positivity by year at each site in the following states with no laws (Iowa, Kentucy, South Carolina, Tennessee, Texas) are shown. The median, 25th and

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75th percentile for monthly THC immunoassy positivity is plotted. The trend *P* value was 0.7814 for Iowa, 0.0545 for Kentucky, <0.0001 for South Carolina, 0.0112 for Tennessee and 0.4710 for Texas. Trend lines are displayed. *indicates a significant difference from the previous year.

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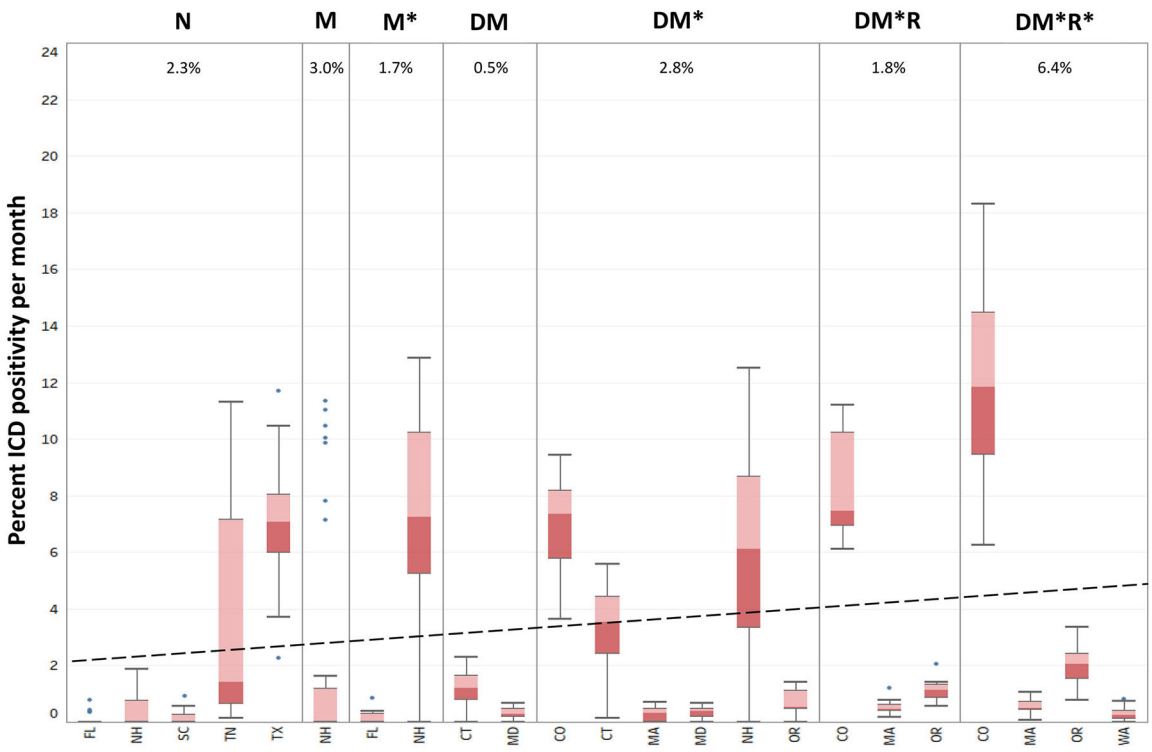

Figure 4.

The International Classification of Diseases (ICD) code percent positivity across states by legalization period. The monthly ICD code positivity for each legalization period and site with data in that period are shown. The median, 25th and 75th percentile for monthly ICD code positivity is plotted. N: No state laws; D: Decriminalized; M: Medical; R: Recreational, *Dispensary Available (M/R). The average percent positivity for each legalization period, combining the sites data, is shown within each box. The trend *P* value for changes in ICD code positivity between legalization periods for all states was <0.0001 and the associated trend line is displayed. The *P* value between states with similar legalization periods was <0.0001 for all legalization periods. California was not included in this figure because it was the only site in the group for which D9-tetrahydrocannabinol (THC) is not part of the urine drug screen panel affecting ICD code positivity. FL: Florida; NH: New Hampshire; SC: South Carolina; TN: Tennessee; TX: Texas; FL: Florida; CT: Connecticut; MD: Maryland; CO: Colorado; MA: Massachusetts; OR: Oregon; WA: Washington.

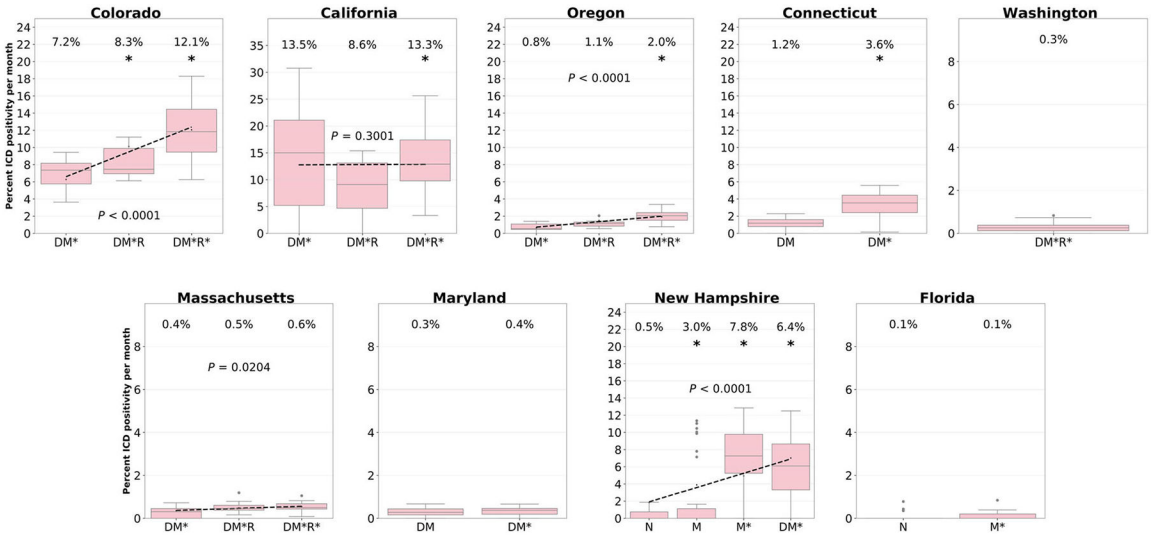

Figure 5.

Average monthly International Classification of Diseases (ICD) code positivity rates per legalization period. Rates of monthly ICD code positivity as legalization progressed at each site in the following states (Colorado, California, Oregon, Connecticut, Washington, Massachusetts, Maryland, New Hampshire, Florida) are shown. The median, 25th and 75th percentile for monthly ICD code positivity is plotted. N: No state laws; D: Decriminalized; M: Medical; R: Recreational, *Dispensary Available (M/R). The trend *P* value for each site with three or more legalization periods (Colorado, California, Oregon, Massachusetts, New Hampshire) and associated trend lines are displayed. *indicates a significant difference from the previous legalization period and *P*-values are available in Supplemental Table 5.

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Table 1a.

Percent change in Δ9-tetrahydrocannabinol immunoassay positivity between sequential legalization periods.

	N-D	N-M	N-M*	N-DM	D-DM	M-M*	M*-DM*	DM-DM*	DM-DMR	DM*-DMR	DMR-DM*R*	DM*R- DM*R*	Cum
CO										3.9		6.3	10.2
CA										0.1		0.2	0.3
OR										0.4		2.9	3.3
WA									3.3		9.2		12.5
MA					1.1			2.4		2.3		2.8	8.6
CT								4.1					4.1
MD				−1.7				2					0.3
NH		0.7				−4.0	8.7						5.4
MO	5.7				3.7								9.4
FL			0.6										0.6
Avg	5.7	0.7	0.6	−1.7	2.4	−4.0	8.7	2.8	3.3	1.7	9.2	3.1	5.5;2.7[†]

Gray shading = significant change between legalization periods shown; all *P*-values <0.0001 except for DM-DMR in Washington (*P* = 0.002), D-DM in Massachusetts (*P* = 0.019) and N-DM in in Maryland (*P* = 0.001).

[†]5.5 = Cumulative Average; 2.7 = weighted average of transitions.

Cum: Cumulative; Avg: Average; N: no state laws; D: decriminalized: M: medical approval prior to dispensaries available; M* = medical dispensaries available;

R: recreational approval prior to dispensaries; R* = recreational dispensaries available; CO: Colorado; CA: California; OR: Oregon; WA: Washington; MA: Massachusetts; CT: Connecticut; MD: Maryland; NH: New Hampshire; MO: Missouri; FL: Florida.

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Table 1b.

Percentage changes in Δ9-tetrahydrocannabinol immunoassay positivity for sequential years in states with no laws.

	2015–2016	2016–2017	2017–2018	2018–2019	Cumulative
KY	2.9	2.4	0.7	−3.3	2.7
SC	1.3	0.5	0.7	−0.1	2.5
TN	2.1	−0.3	0.4	0.3	2.5
TX	−0.8	−0.2	2.6	−3.6	−1.9
Average per year	1.4	0.6	1.1	−1.7	1.0;0.4[†]

Gray shading = significant change between years shown; $P = 0.024$ (2018–2019 in Kentucky), $P = 0.018$ (2015–2016 in Tennessee), $P = 0.024$ (2017–2018 in Texas) and $P = 0.002$ (2018–2019 in Texas).

[†]1.0 = cumulative average; 0.4 = average of transitions per year.

KY: Kentucky; SC: South Carolina; TN: Tennessee; TX: Texas.

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