Cost savings from averted prescription opioid-attributable dental diseases in the United States between 2013 and 2019

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ABSTRACT

INTRODUCTION Between 2013 and 2019, opioid prescriptions in the US declined by about 7% per year. However, little is known about the health and economic impacts of this decline on common dental diseases in adults (i.e. periodontitis, untreated dental caries and edentulism). We sought to assess relationships between prescription opioid use and indicated dental diseases, and to estimate associated epidemiologic and economic impacts of the decline in opioid prescriptions.
METHODS We evaluated NHANES data (2009, 2011, 2013 and 2015 cycles) to measure associations between recent prescription opioid use and indicated dental diseases. We then used an empirical modeling approach to estimate: a) the number of patients directly affected by withheld opioid prescriptions, b) associated changes in the number of

patients with indicated dental diseases, and c) associated changes in direct and indirect costs of care.
RESULTS Estimated one-year risks of untreated caries and edentulism were 1.5% (95% CI: 0.2–2.8, p<0.05) and 2.6% (95% CI: 1.2–4.1, p<0.05) higher in NHANES participants with recent prescription opioid use compared to those without. About 102 million opioid prescriptions were withheld from about 91 million individuals between 2013 and 2019; this may have averted over 1.3 million cases of untreated caries and 2.3 million cases of edentulism, and may have saved up to $1.4 billion in direct and indirect costs.
CONCLUSIONS The decline in opioid prescriptions between 2013 and 2019 may have averted over 3.6 million combined cases of untreated caries and edentulism, and may have saved the US economy over $1.4 billion.

INTRODUCTION

The US has been experiencing an opioid epidemic driven by prescription opioids[1]. With annual opioid prescriptions averaging over 200 million in the last decade, there are about 2 million substance use disorder diagnoses and 50000 overdose deaths each year[1]. The opioid epidemic cost the US over $1 trillion between 2001 and 2007, and the annual cost to society ranges between $89 billion and $117 billion (2018 US$)[2]. This economic burden results from criminal justice involvement (about 9%), direct and indirect healthcare costs (up to 45%), and workplace productivity loss (up to 46%)[3]. Between 2013 and 2019, the previously rising trend in annual opioid prescriptions underwent a reversal. With growing awareness of the opioid epidemic, increasing adoption of safer prescribing practices, and implementation of Prescription Drug Monitoring Programs, annual opioid

prescriptions declined by about 7% per year between 2013 and 2019[4,5]. Expectedly, fewer opioid prescriptions should reduce the number of new opioid-attributable health conditions and associated costs[6]. Indeed, early reports indicate that in 2018, overdose deaths decreased for the first time in almost three decades[7]. However, little is known about other opioid-related health conditions that may have been averted by the decline in opioids prescriptions. In the oral health landscape, this knowledge gap is compounded by unclear associations between prescription opioid use and common dental diseases (i.e. periodontitis, untreated caries and edentulism)[8,9]. To fill these gaps, this study's goals were: a) to evaluate associations between prescription opioid use and common dental diseases, and b) to estimate averted new cases of common dental diseases (and associated cost savings) from the indicated decline in opioid prescriptions.

This study's findings are expected to contribute to the national discourse on impacts of the opioid epidemic.

METHODS

Data sources

National Health and Nutrition Examination Survey (NHANES)
NHANES is a nationally representative survey of the non-institutionalized US civilian population to assess the health and nutritional status of adults and children in the United States[10]. The survey combines interviews with physical examinations, and oral health outcomes are usually assessed by calibrated examiners to minimize measurement error in self-reported outcomes[11]. Other characteristics of NHANES have been previously described[10]. For adequate statistical power, we created two pooled datasets across three NHANES cycles: 2009–2010, 2011–2012, and 2013–2014 cycles to study periodontitis among persons aged ≥30 years; and 2011–2012, 2013–2014, and 2015–2016 cycles to study untreated caries and edentulism among individuals aged ≥20 years.

Opioid Prescriptions in the US
Data on the total number of opioid prescriptions dispensed in the United States between 2012–2019 were obtained from the Centers for Disease Control and Prevention and are presented in Table 1[12]. We estimated the decline in opioid prescriptions as year-on-year differences between 2013 and 2019.

Measures

Oral health outcomes
Oral health measurements in the NHANES datasets include

Table 1. Total number of opioid prescriptions dispensed in the United States 2012–2019

	Annual opioid prescriptions (observed)[f]	Reductions in annual opioid prescriptions[†]
2012	255207954	NA
2013	247090443	8117511
2014	240993021	6097422
2015	226819924	14173097
2016	214881622	11938302
2017	191909384	22972238
2018	168158611	23750773
2019	153260450	14898161
Total	1443113455	101947504

NA: not applicable. Previous years' prescriptions are as follows: 215917663 (2006); 228543773 (2007); 237860213 (2008); 243738090 (2008); 251088904 (2010); and 252167963 (2011). Note the rising opioid prescriptions before 2012. f The data were obtained from the Centers for Disease Control and Prevention (U.S. Opioid Dispensing Rate Maps). † Reductions were calculated as year-on-year differences in annual opioid prescriptions.

probing depth, gingival recession, attachment loss, and indices of periodontal disease (mild, moderate, severe, or any periodontitis). We used available oral health measures to create binary indicators of periodontitis (present or absent based on CDC/American Academy of Periodontology case definitions), untreated caries (≥1 tooth affected vs none) and edentulism (≥1 tooth missing vs none)[13].

Indicator of prescription opioid use
Recent (i.e. in the past 30 days) use of hydrocodone, oxycodone, propoxyphene, codeine, tramadol, opium, morphine, fentanyl, hydromorphone, meperidine, pentazocine, oxymorphone, or tapentadol was also assessed in the indicated NHANES cycles; these data were used to create a binary indicator of recent prescription opioid use.

Others
Control covariates of interest (based on plausible associations with the key independent and/or outcome variables) in the NHANES datasets were gender, age, race/ethnicity, educational level, poverty level, health insurance status, country of birth, veteran status, depressive symptoms, cigarette smoking, alcohol use, marijuana use, methamphetamine use, cocaine use, heroin use, comorbidities (including arthritis, diabetes, thyroid disorders, hypertension, hypercholesterolemia, angina, coronary arterial disease, heart attack, stroke, asthma, bronchitis, emphysema, liver diseases and cancer) and NHANES cycle.

Analyses

Evaluating associations between prescription opioid use and common dental diseases
Logistic regression was used to evaluate each indicator of common dental diseases as a function of recent prescription opioid use and control covariates specified above. An alpha of 0.05 was used to determine statistical significance. The logistic regression models were also used to predict the six-year (i.e. 2009–2014 and 2011–2016) risk differences of indicated dental diseases across respondents with and without recent prescription opioid use (i.e. as differences in respective six-year cumulative incidences). These six-year risk differences were then converted to one-year risk differences using methods described by Fleurence et al.[14].

Averted cases of common dental diseases and associated cost-savings
First, we estimated the number of individuals that would have received the averted opioid prescriptions by assuming that 29% of adults with an opioid prescription have refills within the same year (about 1.6 refills per patient)[15]. We then estimated the number of common dental disease cases affected by the decline in opioid prescriptions as the product of respective one-year risk differences and number of individuals that would have received opioid prescriptions

otherwise.

Associated cost savings were measured in two dimensions: productivity loss and direct costs of initial treatment. Productivity loss was assessed using an approach suggested by the World Health Organization's Commission on Macroeconomics and Health[16]. This approach values one disability-adjusted life year (DALY) at one year of per capita gross domestic product (GDP) to approximate productivity loss[17]. Using this information, we estimated the per capita productivity loss for each indicated dental disease by dividing the product of 2016 per capita GDP and respective 2016 DALYs for individuals aged ≥15 years by the respective number of cases in the US[17-20]. For example, per capita productivity loss for untreated caries was calculated by dividing the product of 2016 US per capita GDP ($58000, World Bank) and total disability adjusted life years for untreated caries in 2016 (73711) by the total number of untreated caries cases in the US for those aged ≥15 years[18]. The number of untreated caries cases in the US was estimated by summing products of prevalence of untreated caries (20%, 26% and 18% in individuals aged 15–19 years, 20–64 years, and ≥65 years, respectively) by the number of individuals in indicated age groups (from the U.S. Census bureau)[21-24]. Similarly, per capita productivity loss for edentulism was calculated by dividing the product of 2016 US per capita GDP and total disability adjusted life years for edentulism in 2016 (662274) by the number of edentulous adults in the US (178 million)[18,25]. Averted productivity loss was calculated as the product of per capita productivity loss and averted cases of indicated dental diseases.

Probabilities and direct costs of initial treatment of periodontitis, caries and edentulism were obtained from various sources. Direct costs of initial treatment for periodontitis were obtained from a study by Albert et al.[26], while direct costs of initial treatment for dental caries were obtained from a study by O'Connell et al.[27]. Per capita direct treatment costs for untreated caries account for the probability of initiating treatment in the index year (0.86), as well as the distribution and average costs of common treatment types (i.e. resin 1 [40% at $175 per case], resin 2+ [39% at $210 per case], amalgam 1 [8% at $129 per case],

amalgam 2+ [8% at $152 per case], tooth extraction [5% at $175 per case] and crown [<1% at $1075 per case])[20,28]. Similarly, per capita direct treatment costs for edentulism account for the probability of initiating treatment in the index year (0.29), as well as the distribution and lowest cost of various treatment types (i.e. single dentures [90% at ≥$600 per case for basic to mid-range], implants [5% assumed at ≥$3000 per case], and dental bridges [5% assumed at ≥$1500 per case]) from a targeted review of different data sources[29-42]. Alternative distributions of use of dental implants and bridges for initial treatment of edentulism were examined in sensitivity analyses. All costs were adjusted to 2020 values using appropriate indices from the United States Bureau of Labor Statistics.

RESULTS

Associations between prescription opioid use and common dental diseases

Estimated measures of association between prescription opioid use and periodontitis, edentulism and untreated caries are presented in Table 2. Estimated one-year risks of untreated caries and edentulism were 1.5% (95% CI: 0.2–2.8, p<0.05) and 2.6% (95% CI: 1.2–4.1, p<0.05) higher in NHANES participants with recent prescription opioid use compared to those without recent prescription opioid use. We found no association between recent prescription opioid use and periodontitis and thus excluded periodontitis from further analyses.

Averted cases of common dental diseases and associated cost-savings

An estimated 102 million opioid prescriptions were witheld from about 91 million individuals between 2013 and 2019, as presented in Table 3. This reduction in opioid prescriptions over the study period may have prevented over 1.3 million cases of untreated caries. With estimated per capita productivity loss and direct treatment costs of $77 and $151, respectively, averted cases of untreated caries resulted in $312 million in cost-savings (i.e. about $105 million in productivity loss and $207 million in direct costs of initial treatment). In the same vein, the decline in opioid

Table 2. Associations between prescription opioid use and untreated caries, edentulism and periodontitis (NHANES 2009, 2011, 2013 and 2015 cycles; N ≥8851)

Oral health outcome	OR (95% CI)	Six-year risk difference (95% CI)[a]	One-year risk difference (95% CI)[b]
Untreated caries	1.40 (1.04–1.90)*	0.084 (0.010–0.159)*	0.015 (0.002–0.028)*
Edentulism (partial or complete)	1.81 (1.32–2.48)*	0.147 (0.070–0.223)*	0.026 (0.012–0.041)*
Periodontitis	1.08 (0.75–1.56)	N/A	N/A

*p<0.05. CI: confidence interval. N/A: not assessed (as the associated odds ratio was not statistically significant). Control covariates in all regression models included gender, age, race/ethnicity, educational level, poverty level, health insurance status, country of birth, number of chronic health conditions, veteran status, depressive symptoms, cigarette smoking, alcohol use, marijuana use, methamphetamine use, cocaine use and heroin use, and NHANES cycle. Untreated caries and edentulism were examined using data from individuals aged ≥20 years that participated in NHANES cycles 2011–2012, 2013–2014, and 2015–2016 (N=11515). Periodontitis was examined using data from individuals aged ≥30 years that participated in NHANES cycles 2009–2010, 2011–2012, and 2013–2014 cycles (N=8851)

Table 3. Estimated cases and costs of common dental diseases averted by the decline in annual opioid prescriptions

Analyses	Averted cases[f]	Productivity losses averted		Direct treatment costs averted		Total cost savings
		Per capita	Total	Per capita	Total	
Untreated caries	1164734	$77	$105 million	$151	$207 million	$312 million
Edentulism	1863574	$241	$570 million	$225	$532 million	$1,102 million

All costs are in 2020 US$. Total cost savings for averted untreated caries and edentulism cases over the study period are US$1.42 billion. ƒ The data were obtained from the Centers for Disease Control and Prevention (U.S. Opioid Dispensing Rate Maps).

prescriptions over the study period may have also prevented over 2.3 million cases of edentulism. With estimated per capita productivity loss and direct treatment costs of $241 and $225, respectively, averted cases of edentulism resulted in over $1.1 billion in cost-savings (i.e. about $570 million in productivity loss and $532 million in direct costs of initial treatment). Hence, total cost savings from averted cases of untreated caries and edentulism due to the decline in opioid prescriptions between 2013 and 2019 are over $1.4 billion. Results were robust to alternative assumptions around distributions of use of dental implants and bridges for initial treatment of edentulism.

DISCUSSION

The evidence presented here suggests that the decline in opioid prescriptions between 2013 and 2019 may have averted over 3.6 million combined cases of untreated caries and edentulism, and may have saved the US economy over $1.4 billion. The cost-savings represent <1% of the total expenditure of oral/dental healthcare in the US and are conservative (e.g. rates and direct costs of initial treatment of edentulism may be higher than assumed and cost savings do not account for medium-term to long-term costs [e.g. from follow-on treatment])[43]. Nevertheless, we expect our findings to inform conversations about the economic impact of the opioid crises and to guide future studies exploring the cost-effectiveness of current/novel strategies for reducing opioid prescriptions[44,45].

Limitations

This study has several limitations. Associations between recent use of prescription opioid and untreated caries/edentulism are most likely confounded by opioid misuse: 1 in 3 individuals receiving prescription opioids misuse them[46]; and opioid misuse cases often experience oral comorbidities from prolonged periods of intoxication and/or opioid-seeking habits that typically occur at the expense of oral hygiene/dental care[47]. While opioid misuse may confound these associations, it strengthens study findings by providing insight into additional benefits of prescribing fewer opioids (i.e. averting cases of opioid misuse [about 26 million individuals], opioid use disorder [about 8 million individuals], opioid overdose [possible deaths] and neonatal abstinence syndrome)[47]. We encourage future studies exploring cost-savings from averting these additional health conditions/events (including the economic value of averting loss of potential years of life and quality-adjusted life years). Other limitations include risks of reverse causation (e.g. opioid prescriptions following wisdom tooth extraction) and misclassification errors (e.g. social desirability bias while self-reporting substance use behaviors), which may lead to biased estimates or Type 2 error. However, available anecdotal evidence suggests that indicated risks are minimal. The estimated 91 million individuals from whom prescription opioids may have been withheld may be an overestimate (from double counting) as some may have received one or more opioid prescriptions within or across several years. Additionally, we viewed untreated caries and edentulism as mutually exclusive oral health conditions; however, available evidence suggests that these conditions are at opposite ends of the same spectrum, and that both conditions could have occurred in the same individual[48]. Severe scarcity of data precluded estimation of uncertainty measures and motivated a recourse to the grey literature for some input data (e.g. costs of initial treatment of edentilism)[29-42]. Lastly, study findings may not extend to populations excluded from NHANES (e.g. persons incarcerated, those in nursing homes and other institutions, and active-duty military personnel).

CONCLUSIONS

The decline in dispensed prescription opioids between 2013 and 2019 may have averted over 3.6 million combined cases of untreated dental caries and edentulism while saving the US economy over $1.4 billion.

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