Surgery Open Science 19 (2024) 44–49

Contents lists available at ScienceDirect

Surgery Open Science

journal homepage: www.journals.elsevier.com/surgery-open-science

Research Paper

Association of substance-use disorder with outcomes of major elective abdominal operations: A contemporary national analysis

Baran Khoraminejad [a,b,1], Sara Sakowitz, MS MPH [a,1], Zihan Gao, MHSc [a], Nikhil Chervu, MD [a,c], Joanna Curry, BA [a], Konmal Ali [a], Syed Shahyan Bakhtiyar, MD MBE [a,d], Peyman Benharash, MD MS [a,c,*]

[a] CORELAB, Department of Surgery, University of California, Los Angeles, Los Angeles, CA, United States of America
[b] Boston University, Boston, MA, United States of America
[c] Department of Surgery, University of California, Los Angeles, Los Angeles, CA, United States of America
[d] Department of Surgery, University of Colorado, Denver, Aurora, CO, United States of America

HIGHLIGHTS

- Among a national cohort undergoing elective abdominal operations 3.0 % had substance use disorder.
- Concurrent substance abuse was associated with greater morbidity and resource utilization.
- Novel in-hospital interventions are needed to mitigate increased perioperative risk.

ARTICLE INFO

Keywords:
Substance use disorder
Substance abuse
Surgical outcomes
Colectomy
Gastrectomy
Esophagectomy
Hepatectomy
Pancreatectomy

ABSTRACT

Background: Affecting >20million people in the U.S., including 4 % of all hospitalized patients, substance use disorder (SUD) represents a growing public health crisis. Evaluating a national cohort, we aimed to characterize the association of concurrent SUD with perioperative outcomes and resource utilization following elective abdominal operations.

Methods: All adult hospitalizations entailing elective colectomy, gastrectomy, esophagectomy, hepatectomy, and pancreatectomy were tabulated from the 2016–2020 National Inpatient Sample. Patients with concurrent substance use disorder, comprising alcohol, opioid, marijuana, sedative, cocaine, inhalant, hallucinogen, or other psychoactive/stimulant use, were considered the *SUD* cohort (others: *nSUD*). Multivariable regression models were constructed to evaluate the independent association between *SUD* and key outcomes.

Results: Of ~1,088,145 patients, 32,865 (3.0 %) comprised the *SUD* cohort. On average, *SUD* patients were younger, more commonly male, of lowest quartile income, and of Black race. *SUD* patients less frequently underwent colectomy, but more often pancreatectomy, relative to *nSUD*.

Following risk adjustment and with *nSUD* as reference, *SUD* demonstrated similar likelihood of in-hospital mortality, but remained associated with increased odds of any perioperative complication (Adjusted Odds Ratio [AOR] 1.17, CI 1.09–1.25). Further, *SUD* was linked with incremental increases in adjusted length of stay (β + 0.90 days, CI +0.68–1.12) and costs (β + $3630, CI +2650–4610), as well as greater likelihood of non-home discharge (AOR 1.54, CI 1.40–1.70).

Conclusions: Concurrent substance use disorder was associated with increased complications, resource utilization, and non-home discharge following major elective abdominal operations. Novel interventions are warranted to address increased risk among this vulnerable population and address significant disparities in postoperative outcomes.

* Corresponding author at: 10833 Le Conte Avenue, UCLA Center for Health Sciences, Room 62-249, Los Angeles, CA 90095, United States of America.
E-mail address: Pbenharash@mednet.ucla.edu (P. Benharash).
@BKhoraminejad (B. Khoraminejad), @sarasakowitz (S. Sakowitz), @CoreLabUCLA, @Aortologist (P. Benharash)

[1] The authors contributed equally to this work.

https://doi.org/10.1016/j.sopen.2024.03.006
Received 18 February 2024; Accepted 15 March 2024
Available online 22 March 2024

Introduction

The substance use crisis in the U.S. represents a public health emergency, with >20 million individuals currently affected and attributable expenditures exceeding $1.02 trillion, annually [1–3]. Over the last two decades, the prevalence of substance use disorder (SUD) has dramatically risen and is now noted in ~4 % of hospitalized patients [4,5]. Prior work has linked SUD with greater perioperative risk, including increased vulnerability to infection, refractory pain, longer duration of hospitalization, and reduced treatment adherence [6–9]. Moreover, chronic SUD contributes to analgesic tolerance and diffuse hyperalgesia, complicating postoperative management and rehabilitation [10,11].

While the association of SUD with perioperative outcomes of orthopedic and cardiovascular procedures is well characterized [6,8,12,13], few have examined this relationship in elective abdominal surgery, which may be complex and generally associated with significant pain [14–16]. A study by Sahara et al. [14] examining patients undergoing abdominal operations during 2007–2014 noted increased complication rates, length of stay, and expenditures in those with SUD. Yet, this work considered outcomes in the period before the onset of the contemporary substance use crisis. Further, while a variety of agents are used by individuals with SUD, most available literature has focused on opiate dependence and generally noted an increased risk of adverse outcomes as well as greater costs [15,17,18]. However, the generalizability of existing work on the association of SUD with outcomes in surgical patients remains limited by methodologic constraints, including the use of dated cohorts and omission of several commonly used substances. Given the increasing prevalence of SUD [19,20] and a growing volume of intra-abdominal operations in the U.S., a contemporary analysis is warranted. These findings could ultimately better inform risk assessment, shared decision making, and targeted quality improvement efforts.

In the present work, we aimed to characterize the association of SUD with clinical outcomes and costs following major abdominal operations using a national dataset. We hypothesized SUD to be independently linked with greater in-hospital mortality, complications, and resource utilization across all operative categories.

Methods

Data source and study cohort

All adult (≥18 years) hospitalizations entailing elective colectomy, gastrectomy, esophagectomy, hepatectomy, and pancreatectomy were identified using the 2016–2020 Nationwide Inpatient Sample (NIS). The NIS is the largest nationwide all-payer inpatient database that utilizes validated algorithms to provide accurate estimates for approximately 97 % of all U.S. hospitalizations each year [21].

Variable definitions and study outcomes

Previously-validated *International Classification of Diseases*, *Tenth Revisions* (ICD-10) diagnosis codes were utilized to identify concurrent substance use disorder, comprising alcohol, opioid, marijuana, sedative, cocaine, inhalant, hallucinogen, or other psychoactive or stimulant use [12,22]. Of note, these diagnosis codes conform with definitions set forth by the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition [23], and have been applied in Healthcare Cost and Utilization Project (HCUP) Statistical Briefs [24] and numerous prior studies [12–15,25].

Patients with diagnosis codes representing substance abuse comprised the *SUD* cohort (others: *nSUD*). Records missing data regarding age, sex, or in-hospital mortality were excluded (<1 %, Fig. 1).

Patient, hospital and operative characteristics were tabulated in accordance with the HCUP Data Dictionary [26]. Patients' burden of chronic illness was quantified using the van Walraven modification of the Elixhauser Comorbidity Index [27]. Specific comorbidities and perioperative complications were defined according to relevant ICD-10 diagnosis and procedure codes, as described elsewhere [28]. Operative approach was stratified as open, laparoscopic, or robotic. To calculate hospitalization costs, center-specific cost-to-charge ratios were applied to overall charges and then inflation-adjusted using the 2020 Personal Healthcare Price Index [29].

Our primary outcome of interest was in-hospital mortality. We secondarily considered perioperative complications and resource utilization, including duration of hospitalization (LOS), expenditures, and discharge to extended care facilities.

Statistical analysis

Continuous variables are presented as median with interquartile range, while categorical variables are reported as percentages (%). We used the Mann-Whitney *U* and Chi-squared tests to assess the significance of inter-cohort differences, as appropriate. The significance of temporal trends was determined using Cuzick's nonparametric test for trend (nptrend) [30].

Multivariable logistic and linear regression models were developed to ascertain the independent association between SUD and outcomes of interest. To minimize model bias and collinearity, elastic net regularization was utilized to select all covariates [31]. Models were subsequently evaluated using receiver operating characteristics or the coefficient of determination. Logistic model outputs are reported as adjusted odds ratios (AOR) while those for linear models are reported as β-coefficients (β), both with 95 % confidence intervals (CI).

A sensitivity analysis was performed utilizing entropy balancing to further adjust for inter-cohort differences. This method applies pseudo-propensity scores to ascertain optimal sample weights for covariate balance between groups, while retaining the entire study population for analysis [32]. Notably, this method has been demonstrated to be more robust than propensity matching [33].

All statistical analyses were conducted using Stata 16.1 (StataCorp LLC, College Station, TX). Statistical significance was set at α = 0.05. This study was deemed exempt from full review by the Institutional

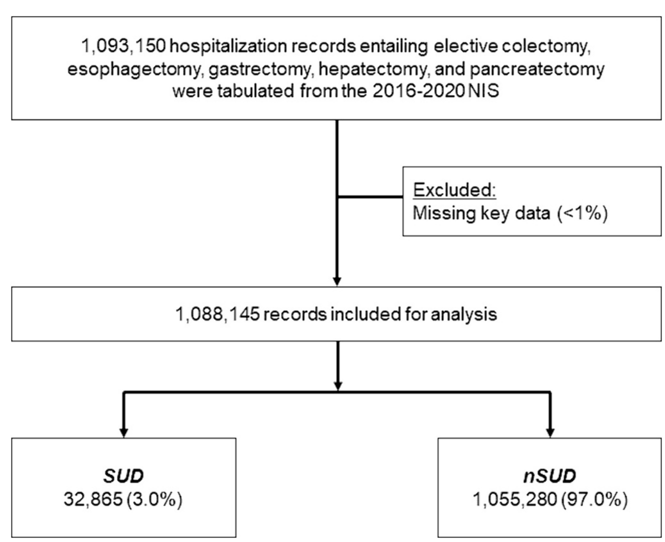

Fig. 1. Study CONSORT diagram.
Of an estimated 1,093,150 records tabulated from the 2016–2020 National Inpatient Sample (NIS), 1,088,145 were included for analysis. Of these, 32,865 (3.0%) had concurrent substance abuse, comprising alcohol, opioid, marijuana, sedative, cocaine, inhalant, hallucinogen, or other psychoactive or stimulant use, and were considered the *SUD* cohort.

Review Board at the University of California, Los Angeles.

Results

Of an estimated 1,088,145 patients hospitalized for elective abdominal operations, 32,865 (3.0 %) were considered the *SUD* group. Of these, 54.1 % were dependent on alcohol, 14.4 % on opioids, 21.7 % on marijuana, 2.9 % on cocaine, 1.9 % on sedatives, and 4.9 % on other stimulant or psychoactive substances. *SUD* patients less often underwent colectomy (69.7 vs 76.3 %), but more often pancreatectomy (10.8 vs 7.8 %, P < 0.001), compared to nSUD.

A complete characterization of the study sample is detailed in Table 1. On average, the *SUD* cohort was younger (58 [50–66] vs 63 [52–72], P < 0.001), more frequently male (68.1 vs 46.2 %, P < 0.001), and more often treated at hospitals in the West (23.6 vs 18.2 %, P < 0.001, Fig. 2). Relative to *nSUD*, *SUD* patients were more commonly of lowest quartile income (28.3 vs 23.3 %, P < 0.001), of Black race (11.7 vs 9.4 %, P < 0.001), and insured by Medicaid (20.5 vs 8.1 %, P < 0.001). These patients had a higher Elixhauser comorbidity index (4 [3–5] vs 2 [1–4], P < 0.001) and more often presented with chronic pulmonary disease (22.4 vs 14.4 %, P < 0.001), liver disease (16.6 vs 4.8 %, P < 0.001), and cardiac arrhythmias (15.6 vs 13.6 %, P < 0.001).

Table 1
Demographic, clinical, and hospital characteristics.
Reported as proportions unless otherwise noted. Statistical significance was set at α = 0.05.
**IQR*, inter-quartile range.

	SUD (n = 32,865)	*nSUD* (n = 1,055,280)	P-value
Age (years [IQR])	58 [50–66]	63 [52–72]	<0.001
Female (%)	31.9	53.8	<0.001
Elixhauser Comorbidity Index (median [IQR])	4 [3–5]	2 [1–4]	<0.001
Operation (%)			<0.001
Colectomy	69.7	76.3	
Esophagectomy	2.7	1.3	
Gastrectomy	9.1	8.4	
Hepatectomy	7.8	6.2	
Pancreatectomy	10.8	7.8	
Operative approach (%)			<0.001
Open	62.0	54.6	
Laparoscopic	25.5	30.5	
Robotic	12.5	15.0	
Income percentile (%)			<0.001
>75 %	19.8	24.9	
51–75 %	25.0	25.9	
26–50 %	26.8	25.8	
0–25 %	28.3	23.3	
Insurance coverage (%)			<0.001
Private	36.4	43.0	
Medicare	37.0	45.0	
Medicaid	20.5	8.1	
Other Payer	6.1	4.0	
Race/Ethnicity (%)			<0.001
White	76.4	76.5	
Black	11.7	9.4	
Hispanic	7.5	8.1	
Asian/Pacific Islander	1.2	2.8	
Other	3.1	3.2	
Comorbidities (%)			
Congestive heart failure	7.0	5.0	<0.001
Cancer	46.3	46.3	0.99
Peripheral vascular disease	4.9	3.6	<0.001
Hypertension	50.9	50.2	0.26
Cardiac arrhythmias	15.6	13.6	<0.001
Chronic pulmonary disease	22.4	14.4	<0.001
Liver disease	16.6	4.8	<0.001
Coagulopathy	6.3	3.2	<0.001
Cerebrovascular disorders	6.2	2.9	<0.001
Hospital region (%)			<0.001
Northeast	17.8	19.2	
Midwest	23.8	23.9	
South	34.8	38.7	
West	23.6	18.2	
Hospital teaching status (%)			0.38
Non-Metropolitan	78.7	78.0	
Metropolitan Non-Teaching	15.5	16.1	
Metropolitan Teaching	5.7	5.9	

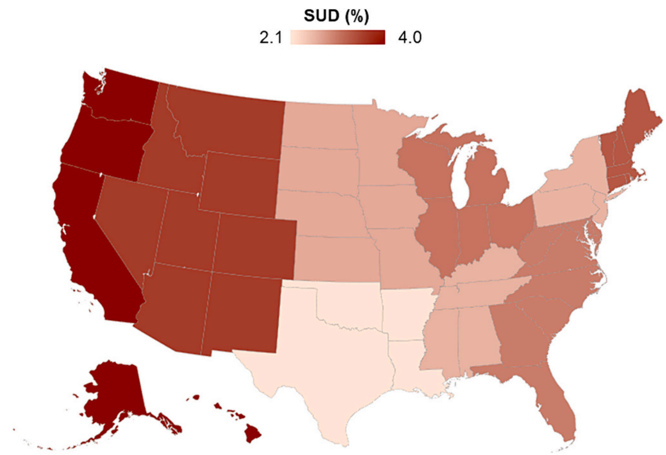

Fig. 2. Geospatial mapping of the SUD cohort.
The study cohort was further stratified by hospital region and concurrent substance abuse. Of all patients presenting for elective abdominal operations, the proportion considered *SUD* ranged from 2.1 % (Arkansas, Oklahoma, Louisiana, Texas) to 4.0 % (Alaska, California, Hawaii, Oregon, and Washington).

On bivariate comparison, the *SUD* cohort more frequently experienced in-hospital mortality (1.5 vs 0.9 %, P < 0.001) and any perioperative complication (25.1 vs 15.2 %, P < 0.001), relative to *nSUD*. Indeed, *SUD* patients faced higher incidence of gastrointestinal (5.7 vs 3.3 %, P < 0.001), infectious (7.4 vs 3.7 %, P < 0.001), and respiratory complications (7.7 vs 3.5 %, P < 0.001). Such patients also more commonly required discharge to extended care facilities (10.5 vs 7.0 %, P < 0.001, Table 2).

Following risk adjustment and with *nSUD* as reference, *SUD* demonstrated similar likelihood of in-hospital mortality, but remained associated with greater odds of any perioperative complication (AOR 1.17, CI 1.09–1.25, Fig. 3). Specifically, *SUD* was linked with increased likelihood of gastrointestinal complications (AOR 1.17 CI 1.09–1.25), infection (AOR 1.34, CI 1.20–1.50), respiratory sequelae (AOR 1.54, CI 1.38–1.72), thromboembolism (AOR 2.05, CI 1.45–2.90), and need for blood transfusion (AOR 1.18, CI 1.06–1.30). Further, *SUD* demonstrated greater adjusted LOS (β + 0.90 days, CI +0.68–1.12) and costs (β + $3630, CI +2650–4610). This remained true after stratification by operation, such that *SUD* consistently faced greater risk-adjusted rates of any perioperative complication (Fig. 4) and increased hospitalization expenditures (Fig. 5). Notably, *SUD* patients also experienced increased odds of non-home discharge (AOR 1.54, CI 1.40–1.70), as well as a three-fold increase in likelihood of discharge against medical advice (AOR 3.49, CI 2.36–5.17).

A sensitivity analysis utilizing entropy balancing demonstrated similar findings as our main analysis, such that the *SUD* cohort remained associated with increased odds of gastrointestinal (AOR 1.23, CI 1.09–1.39), infectious (AOR 1.38, CI 1.24–1.53), respiratory (AOR 1.51, CI 1.35–1.69), and thromboembolic (AOR 1.62, CI 1.25–2.10) complications. Compared to *nSUD*, *SUD* was also linked with increased LOS (β + 0.85 days, CI +0.59–1.10), expenditures (β + $3562, CI +2491–4634), and likelihood of non-home discharge (AOR 1.23, CI 1.12–1.34).

Table 2
Unadjusted and adjusted outcomes.
Outcomes reported as proportions or as Adjusted Odds Ratio (AOR) with 95 % confidence intervals (95 % CI). Reference: *nSUD*.
**IQR*, interquartile range; *USD*, United States dollar.

	Unadjusted			Adjusted		
	SUD	*nSUD*	P	*SUD*	95 % CI	P
Clinical outcomes						
In-hospital mortality	1.5	0.9	<0.001	0.94	0.74–1.21	0.64
Any complication	25.1	15.2	<0.001	1.17	1.09–1.25	<0.001
Gastrointestinal complications	5.7	3.3	<0.001	1.21	1.07–1.37	0.002
Cardiac complications	1.3	0.8	<0.001	1.16	0.91–1.48	0.24
Stroke complications	0.1	0.1	0.55	0.96	0.48–1.91	0.91
Infectious complications	7.4	3.7	<0.001	1.34	1.20–1.50	<0.001
Respiratory complications	7.7	3.5	<0.001	1.54	1.38–1.72	<0.001
Blood transfusion	8.1	5.4	<0.001	1.18	1.06–1.30	0.002
Thromboembolism	1.1	0.6	<0.001	2.05	1.45–2.90	<0.001
Acute kidney injury	9.4	6.5	<0.001	0.82	0.75–0.91	<0.001
Non-home discharge	10.5	7.0	<0.001	1.54	1.40–1.70	<0.001
Discharge against medical advice	<0.1 %	0.5 %	<0.001	3.49	2.36–5.17	<0.001
Resource utilization						
Duration of stay (days) [IQR]	6 [4–9]	4 [3–7]	<0.001	+0.90	+0.68–1.12	<0.001
Costs (USD $1000) [IQR]	24.2 [16.3–39.4]	18.9 [13.5–28.7]	<0.001	+3.63	+2.65–4.61	<0.001

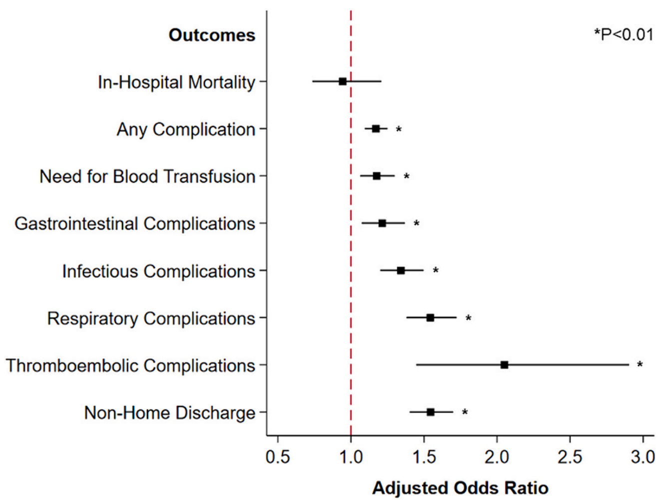

Fig. 3. Association of SUD with perioperative outcomes.
Following risk adjustment and with *nSUD* as reference, *SUD* remained associated with similar likelihood of in-hospital mortality, but greater odds of any perioperative complication. Specifically, *SUD* demonstrated increased likelihood of gastrointestinal, infection, respiratory, and thromboembolic complications, as well as need for blood transfusion. Further, *SUD* was linked with higher odds of discharge to extended care facilities, relative to *nSUD*.
* indicates statistical significance, P < 0.01. Error bars represent 95 % confidence intervals.

Discussion

In the present nationally representative analysis, we found concurrent substance abuse to be associated with similar mortality, but greater complications following elective abdominal operations. Moreover, SUD was linked with greater duration of stay and hospitalization costs. Lastly, SUD patients more often required discharge to extended care facilities. With implications for the care of this complex cohort, several of these findings merit further discussion.

Patients with concurrent SUD represent a complex, but growing, surgical cohort. We identified 3 % of the sample to present with SUD, with the largest proportion of hospitalized patients treated in California, Washington, Oregon, Hawaii, and Alaska. Interestingly, the western and southern U.S. are noted to face increased burden of SUD, but the lowest

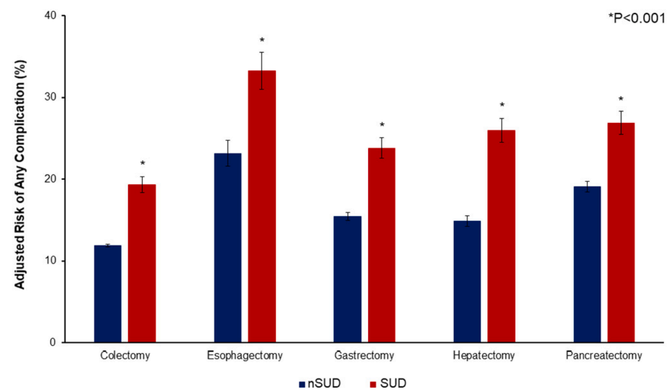

Fig. 4. Adjusted risk of perioperative complications, stratified by operation.
Compared to *nSUD*, the *SUD* cohort demonstrated increased adjusted likelihood of any perioperative complication following colectomy (19.3 vs 11.9 %), esophagectomy (33.3 vs 23.2 %), gastrectomy (23.8 vs 15.4 %), hepatectomy (26.0 vs 14.9 %), and pancreatectomy (26.9 vs 19.1 %, all P < 0.001).

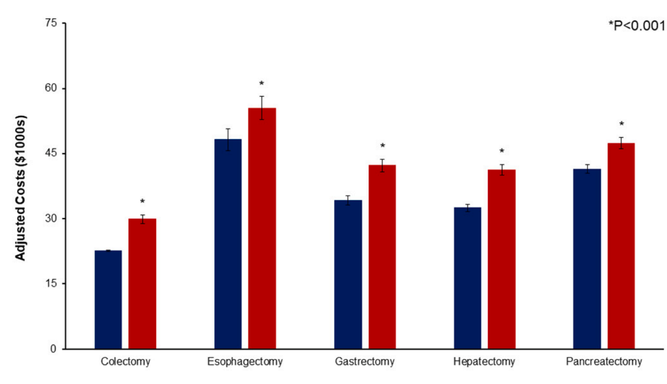

Fig. 5. Adjusted hospitalization expenditures, stratified by operation.
Relative to *nSUD*, *SUD* patients experienced increased adjusted hospitalization costs across all operations considered, including colectomy (*SUD* $29,878 vs *nSUD* 22,582), esophagectomy ($55,479 vs 48,215), gastrectomy ($42,219 vs 34,213), hepatectomy ($41,256 vs 32,487) and pancreatectomy ($47,374 vs 41,452, all P < 0.001).

utilization of treatment services, potentially contributing to the greater SUD prevalence noted in this study [34,35]. Relative to others, these patients were younger, more often socioeconomically disadvantaged, insured by Medicaid, and of Black race. Given such sociodemographic factors have been independently linked with both reduced access to and outcomes following surgical care, they may both compound and magnify SUD-associated inequities. Further, in line with prior reports [36,37], we found the SUD cohort to have a significantly higher comorbidity burden. Yet, after adjusting for these demographic and clinical characteristics, SUD remained persistently associated with inferior postoperative outcomes, relative to others.

Importantly, we noted patients with SUD to face a ~17 % increase in relative risk of any perioperative complication, including gastrointestinal, respiratory, and infectious sequelae. These findings align with prior work reporting chronic opioid users to face increased complications following elective hysterectomy, ventral hernia repair, and bariatric surgery [17]. Notably, some have attributed this greater vulnerability to stem from inadequate analgesia. Patients with SUD have been reported to exhibit higher narcotic requirements and greater susceptibility to perioperative pain [6,8,38,39]. Poor pain control leading to insufficient pulmonary hygiene could contribute to higher risk of respiratory failure and pneumonia, especially as these patients may already experience SUD-related impaired mucociliary clearance or pulmonary inflammation [40]. Efforts to address postoperative pain through multimodal approaches, including epidurals, regional blocks, and non-pharmacologic mechanisms, may increase incentive spirometer use and encourage improved pulmonary toilet. Chronic substance use has also been linked with broad immunosuppression [41–44] and impaired gastrointestinal function [45]. Ideally, such patients would receive outpatient treatment for SUD before proceeding with elective surgery. However, as this may not be possible, particularly among patients undergoing resection for malignancy, broadened screening upon admission could identify those most at risk for adverse postoperative outcomes. Even among patients who received treatment preoperatively, though, SUD should be considered a chronic condition, in which challenges with symptoms and adherence may persist indefinitely [46]. Therefore, these patients may benefit from specifically-designed hospital care pathways and well-designed electronic health record order sets focused on improved preoperative risk mitigation, including careful antibiotic selection, perioperative coordination with pain specialists, and slow resumption of diet. Yet, we additionally recognize the influence of structural racism on U.S. drug policy, substance use screening, and access to care [47]. Therefore, every effort must be taken to ensure more widespread SUD screening is not targeted to any one community or group, and yields improved care, without greater patient harm.

Following adjustment for complications, SUD remained associated with increased duration of stay, hospitalization expenditures, and discharge to extended care facilities, including skilled nursing facilities and acute rehabilitation centers. Given this, earlier integration of social work and discharge planning could potentially reduce unnecessary delays in discharge, and ensure these patients can access necessary services and support for their postoperative recovery. Of note, while overall rates remained low, the SUD cohort also faced an over three-fold increase in likelihood of discharge against medical advice. Discharge against medical advice may stem from inadequate SUD treatment, uncontrolled pain, or experiences during hospitalization that reflect discrimination or stigma [48], and has been linked with negative health effects [49]. While post-discharge outcomes were unavailable for this analysis, prior studies have reported up to a 150 % increase in readmission rates among patients with opioid dependence [9,15]. Future work is needed to evaluate both discharge against medical advice and readmission among the broader SUD cohort, and design interventions to boost access to and adherence with follow-up care.

The present study has several important limitations. As an administrative database, the NRD relies on ICD coding, which is subject to clinician, hospital, and regional variation in practice. Granular physiologic, pharmacologic, laboratory, or imaging data was not detailed. We also could not access intraoperative details, including blood loss, extent of disease, or operative time. Among the patients undergoing resection for cancer, we could not identify stage nor receipt of neoadjuvant therapy. Importantly, information regarding duration of substance use, regularity, or dose was not reported. Further, we could not assess whether patients had received or were currently engaging with substance use disorder treatment services or rehabilitation. While the administrative codes utilized in this study to ascertain SUD are highly specific [50], they may not fully capture the broader patient population facing SUD. Broader screening and utilization of these codes as part of electronic health record documentation may improve their sensitivity. Although we adjusted for inter-cohort differences using entropy balancing, unknown confounders may have remained. Despite these limitations, we applied robust statistical methods and the largest available national database to examine this topic.

In conclusion, concurrent substance abuse is associated with increased complications, resource utilization, and non-home discharge following elective abdominal operations. Patents should be screened for SUD upon hospital admission, and clinicians should both recognize and take action to mitigate increased risk in the perioperative period. Given the continued and unrelenting substance abuse epidemic, additional work is needed to develop and implement in-hospital interventions for this group, and address significant disparities in postoperative outcomes.

Ethics approval

This study was deemed exempt from full review by the Institutional Review Board at the University of California, Los Angeles, due to the deidentified nature of the NIS.

Funding sources

The authors have no funding sources to report.

COI statement and separate funding statement

The authors of this manuscript have no related conflicts of interest or disclosures to declare. Additionally, the authors have no funding sources to report.

CRediT authorship contribution statement

Baran Khoraminejad: Data curation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **Sara Sakowitz:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Visualization, Writing – original draft, Writing – review & editing. **Zihan Gao:** Visualization, Writing – original draft, Formal analysis. **Nikhil Chervu:** Formal analysis, Investigation, Methodology, Supervision, Validation, Writing – review & editing. **Joanna Curry:** Methodology, Validation, Visualization, Writing – review & editing. **Konmal Ali:** Visualization, Writing – review & editing. **Syed Shahyan Bakhtiyar:** Project administration, Validation, Writing – review & editing, Supervision. **Peyman Benharash:** Conceptualization, Methodology, Project administration, Resources, Writing – review & editing, Supervision.

Declaration of competing interest

The authors have no related conflicts of interest or disclosures to declare.

References

[1] Rudd RA. Increases in drug and opioid-involved overdose deaths — United States, 2010–2015. MMWR Morb Mortal Wkly Rep 2016:65. https://doi.org/10.15585/mmwr.mm655051e1.

[2] Florence CS, Zhou C, Luo F, Xu L. The economic burden of prescription opioid overdose, abuse, and dependence in the United States, 2013. Med Care 2016;54(10):901. https://doi.org/10.1097/MLR.0000000000000625.

[3] Lipari R, Van Horn S. Trends in substance use disorders among adults aged 18 or older. Center for Behavioral Health Statistics and Quality, Substance Abuse and Mental Health Services Administration; 2017.

[4] French R, Aronowitz SV, Brooks Carthon JM, Schmidt HD, Compton P. Interventions for hospitalized medical and surgical patients with opioid use disorder: a systematic review. Subst Abus 2022;43(1):495–507. https://doi.org/10.1080/08897077.2021.1949663.

[5] Karaca Z, Moore BJ. Costs of emergency department visits for mental and substance use disorders in the United States, 2017. In: Healthcare Cost and Utilization Project (HCUP) statistical briefs. Agency for Healthcare Research and Quality (US); 2020. http://www.ncbi.nlm.nih.gov/books/NBK558212/. [Accessed 18 November 2023].

[6] Rozell JC, Courtney PM, Dattilo JR, Wu CH, Lee GC. Preoperative opiate use independently predicts narcotic consumption and complications after total joint arthroplasty. J Arthroplasty 2017;32(9):2658–62. https://doi.org/10.1016/j.arth.2017.04.002.

[7] Jimenez Ruiz F, Warner NS, Acampora G, Coleman JR, Kohan L. Substance use disorders: basic overview for the anesthesiologist. Anesth Analg 2023;137(3):508. https://doi.org/10.1213/ANE.0000000000006281.

[8] Jain N, Phillips FM, Weaver T, Khan SN. Preoperative chronic opioid therapy: a risk factor for complications, readmission, continued opioid use and increased costs after one- and two-level posterior lumbar fusion. Spine 2018;43(19):1331–8. https://doi.org/10.1097/BRS.0000000000002609.

[9] Gupta A, Nizamuddin J, Elmofty D, et al. Opioid abuse or dependence increases 30-day readmission rates after major operating room procedures: a National Readmissions Database study. Anesthesiology 2018;128(5):880–90. https://doi.org/10.1097/ALN.0000000000002136.

[10] Trang T, Al-Hasani R, Salvemini D, Salter MW, Gutstein H, Cahill CM. Pain and poppies: the good, the bad, and the ugly of opioid analgesics. J Neurosci 2015;35(41):13879–88. https://doi.org/10.1523/JNEUROSCI.2711-15.2015.

[11] Hina N, Fletcher D, Poindessous-Jazat F, Martinez V. Hyperalgesia induced by low-dose opioid treatment before orthopaedic surgery: an observational case–control study. Eur J Anaesthesiol 32(4):255–261. doi:https://doi.org/10.1097/EJA.0000000000000197.

[12] Madrigal J, Sanaiha Y, Hadaya J, Dhawan P, Benharash P. Impact of opioid use disorders on outcomes and readmission following cardiac operations. https://heart.bmj.com/content/107/11/909.abstract. [Accessed 17 December 2023].

[13] Dewan KC, Dewan KS, Idrees JJ, et al. Trends and outcomes of cardiovascular surgery in patients with opioid use disorders. JAMA Surg 2019;154(3):232–40. https://doi.org/10.1001/jamasurg.2018.4608.

[14] Sahara K, Paredes AZ, Mehta R, et al. Potential disease burden of patients with substance abuse undergoing major abdominal surgery: a propensity score-matched analysis. Surgery 2019;166(6):1181–7. https://doi.org/10.1016/j.surg.2019.06.018.

[15] Song Y, Tang R, Roses RE, et al. Opioid use disorder is associated with complications and increased length of stay after major abdominal surgery. Ann Surg 274(6):992–1000. doi:https://doi.org/10.1097/SLA.0000000000003697.

[16] Kulshrestha S, Bunn C, Gonzalez R, Afshar M, Luchette FA, Baker MS. Unhealthy alcohol and drug use is associated with an increased length of stay and hospital cost in patients undergoing major upper gastrointestinal and pancreatic oncologic resections. Surgery 2021;169(3):636–43. https://doi.org/10.1016/j.surg.2020.07.059.

[17] Waljee J, Cron D, Steiger R, Zhong L, Englesbe M, Brummett C. The effect of preoperative opioid exposure on healthcare utilization and expenditures following elective abdominal surgery. Ann Surg 2017;265(4):715–21. https://doi.org/10.1097/SLA.0000000000002117.

[18] Cron DC, Englesbe MJ, Bolton CJ, et al. Preoperative opioid use is independently associated with increased costs and worse outcomes after major abdominal surgery. Ann Surg 2017;265(4):695. https://doi.org/10.1097/SLA.0000000000001901.

[19] Fernandez AC, Waljee JF, Gunaseelan V, Brummett CM, Englesbe MJ, Bicket MC. Prevalence of unhealthy substance use and associated characteristics among patients presenting for surgery. Ann Surg 2023;278(4):e740. https://doi.org/10.1097/SLA.0000000000005767.

[20] Zwolinski NM, Patel KS, Vadivelu N, Kodumudi G, Kaye AD. ERAS protocol options for perioperative pain management of substance use disorder in the ambulatory surgical setting. Curr Pain Headache Rep 2023;27(5):65–79. https://doi.org/10.1007/s11916-023-01108-3.

[21] Healthcare Cost and Utilization Project. Overview of the National (Nationwide) Inpatient Sample (NIS). https://www.hcup-us.ahrq.gov/nisoverview.jsp. [Accessed 15 December 2021].

[22] Peterson C, Li M, Xu L, Mikosz CA, Luo F. Assessment of annual cost of substance use disorder in US hospitals. JAMA Netw Open 2021;4(3):e210242. https://doi.org/10.1001/jamanetworkopen.2021.0242.

[23] Diagnostic and Statistical Manual of Mental Disorders: DSM-5™, 5th ed. American Psychiatric Publishing, Inc.; 2013:xliv, 947. doi:https://doi.org/10.1176/appi.books.9780890425596.

[24] Owens P, Fingar K, McDermott K, Muhuri P, Heslin KC. Statistical brief #249: inpatient stays involving mental and substance use disorders, 2016. Accessed December 7, 2023, Agency for Healthcare Research and Quality; 2019. www.hcup-us.ahrq.gov/reports/statbriefs/sb249-Mental-Substance-Use-Disorder-Hospital-Stays-2016.pdf.

[25] Menendez ME, Ring D, Bateman BT. Preoperative opioid misuse is associated with increased morbidity and mortality after elective orthopaedic surgery. Clin Orthop 2015;473(7):2402–12. https://doi.org/10.1007/s11999-015-4173-5.

[26] Healthcare Cost and Utilization Project. NIS description of data elements. https://www.hcup-us.ahrq.gov/db/nation/nis/nisdde.jsp. [Accessed 15 March 2022].

[27] van Walraven C, Austin PC, Jennings A, Quan H, Forster AJ. A modification of the Elixhauser comorbidity measures into a point system for hospital death using administrative data. Med Care 2009;47(6):626–33.

[28] Madrigal J, Mukdad L, Han AY, et al. Impact of hospital volume on outcomes following head and neck cancer surgery and flap reconstruction. Laryngoscope 2021. https://doi.org/10.1002/lary.29903.

[29] Agency for Healthcare Research and Quality. Using appropriate price indices for expenditure comparisons. https://meps.ahrq.gov/about_meps/Price_Index.shtml. [Accessed 15 March 2022].

[30] Cuzick J. A Wilcoxon-type test for trend. Stat Med 1985;4(1):87–90.

[31] Zou H, Hastie T. Regularization and variable selection via the elastic net. J R Stat Soc Series B Stat Methodology 2005;67(2):301–20. https://doi.org/10.1111/j.1467-9868.2005.00503.x.

[32] Hainmueller J. Entropy balancing for causal effects: a multivariate reweighting method to produce balanced samples in observational studies. Polit Anal 2012;20(1):25–46. https://doi.org/10.1093/pan/mpr025.

[33] Zhao Q, Percival D. Entropy balancing is doubly robust. J Causal Inference 2017;5:1. https://doi.org/10.1515/jci-2016-0010.

[34] McAuliffe WE, Dunn R. Substance abuse treatment needs and access in the USA: interstate variations. Addiction 2004;99(8):999–1014. https://doi.org/10.1111/j.1360-0443.2004.00783.x.

[35] Mattson CL, Tanz LJ, Quinn K, Kariisa M, Patel P, Davis NL. Trends and geographic patterns in drug and synthetic opioid overdose deaths — United States, 2013–2019. Morb Mortal Wkly Rep 2021;70(6):202–7. https://doi.org/10.15585/mmwr.mm7006a4.

[36] Shen Y, Lo-Ciganic WH, Segal R, Goodin AJ. Prevalence of substance use disorder and psychiatric comorbidity burden among pregnant women with opioid use disorder in a large administrative database, 2009–2014. J Psychosom Obstet Gynecol 2020;0(0):1–7. https://doi.org/10.1080/0167482X.2020.1727882.

[37] Lindsay AR, Shearer RD, Bart G, Winkelman TNA. Trends in substance use disorder-related admissions at a safety-net hospital, 2008–2020. J Addict Med 2022;16(3):360–3. https://doi.org/10.1097/ADM.0000000000000896.

[38] Ward EN, Quaye ANA, Wilens TE. Opioid use disorders: perioperative management of a special population. Anesth Analg 2018;127(2):539–47. https://doi.org/10.1213/ANE.0000000000003477.

[39] Jage J, Bey T. Postoperative analgesia in patients with substance use disorders: part I. Acute Pain 2000;3(3):29–44. https://doi.org/10.1016/S1366-0071(00)80027-3.

[40] Sayal P, Bateman BT, Menendez M, Eikermann M, Ladha KS. Opioid use disorders and the risk of postoperative pulmonary complications. Anesth Analg 2018;127(3):767. https://doi.org/10.1213/ANE.0000000000003307.

[41] Mora AL, Salazar M, Pablo-Caeiro J, et al. Moderate to high use of opioid analgesics are associated with an increased risk of *Clostridium difficile* infection. Am J Med Sci 2012;343(4):277–80. https://doi.org/10.1097/MAJ.0b013e31822f42eb.

[42] Brack A, Rittner HL, Stein C. Immunosuppressive effects of opioids— clinical relevance. J Neuroimmune Pharmacol 2011;6(4):490–502. https://doi.org/10.1007/s11481-011-9290-7.

[43] Wei Y, Shah R. Substance use disorder in the COVID-19 pandemic: a systematic review of vulnerabilities and complications. Pharmaceuticals 2020;13(7):155. https://doi.org/10.3390/ph13070155.

[44] Baillargeon J, Polychronopoulou E, Kuo YF, Raji MA. The impact of substance use disorder on COVID-19 outcomes. Psychiatr Serv 2021;72(5):578–81. https://doi.org/10.1176/appi.ps.202000534.

[45] Gan TJ, Robinson SB, Oderda GM, Scranton R, Pepin J, Ramamoorthy S. Impact of postsurgical opioid use and ileus on economic outcomes in gastrointestinal surgeries. Curr Med Res Opin 2015;31(4):677–86. https://doi.org/10.1185/03007995.2015.1005833.

[46] Schuckit MA. Treatment of opioid-use disorders. N Engl J Med 2016;375(4):357–68. https://doi.org/10.1056/NEJMra1604339.

[47] Kunins HV. Structural racism and the opioid overdose epidemic: the need for antiracist public health practice. J Public Health Manag Pract 2020;26(3):201. https://doi.org/10.1097/PHH.0000000000001168.

[48] Simon R, Snow R, Wakeman S. Understanding why patients with substance use disorders leave the hospital against medical advice: a qualitative study. Subst Abus 2020;41(4):519–25. https://doi.org/10.1080/08897077.2019.1671942.

[49] Southern WN, Nahvi S, Arnsten JH. Increased risk of mortality and readmission among patients discharged against medical advice. Am J Med 2012;125(6):594–602. https://doi.org/10.1016/j.amjmed.2011.12.017.

[50] Rowe CL, Santos GM, Kornbluh W, Bhardwaj S, Faul M, Coffin PO. Using ICD-10-CM codes to detect illicit substance use: a comparison with retrospective self-report. Drug Alcohol Depend 2021;221:108537. https://doi.org/10.1016/j.drugalcdep.2021.108537.