Research Square

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Community-Level Health Indices and New Persistent Opioid Use: An Analysis of Surgical Patients in an Appalachian Population

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Abstract

Background

Persistent post-operative opioid use (PPOU) contributes to the North American opioid crisis, with 7–10% of patients continuing to refill opioid prescriptions 90 days or longer after surgery. This study investigates the relationship between community-level indices (including zip code and census tract) standard determinants of health, and their ability to correlate with the risk for individual surgical patients having PPOU.

Methods

We conducted a retrospective observational study of 913 opioid-naïve patients who underwent colectomy, mastectomy, or nephrectomy at The University of Tennessee Medical Center between 2018 and 2022. Four validated public health tools were utilized to determine if they were associated with patients at risk: the CDC's Social Vulnerability Index (SVI), the Vizient Vulnerability Index (VVI), the Distressed Community Index (DCI), and the Community Needs Index (CNI). Census tract and zip codes were used to obtain the corresponding scores. The primary outcome was PPOU, defined as opioid prescription at discharge plus ≥ 1 additional opioid prescription between 60–90 days. Univariate and multivariable logistic regression models assessed associations with PPOU, adjusting for demographic, psychosocial, and surgical factors.

Results

PPOU occurred in 8.6% (73/913) of patients. Patients with PPOU had longer hospital stays (median 2.7 vs 2.1 days, $p = 0.040$) and were more likely to undergo total/radical resection versus partial (57.5% vs 33.6%, $p < 0.001$), corresponding to 2.7-fold increased odds of PPOU (OR 2.68, 95% CI 1.65–4.36). No significant differences were observed in demographics, psychiatric history, BMI, recreational drug use, or perioperative nerve block use. None of the community-level indices were associated with PPOU in univariate or multivariate analysis (all $p > 0.15$). Ninety-day readmission was strongly associated with PPOU (adjusted OR ≈ 7.0, $p < 0.001$).

Conclusion

This Appalachian cohort's community-level indices were not associated with individual PPOU, suggesting that ecological metrics may have limited utility for patient-level opioid risk stratification. Postoperative clinical course and surgical magnitude were strongly associated with PPOU, highlighting actionable perioperative intervention targets such as optimizing recovery pathways and monitoring patients with readmission or extensive procedures. Future research should evaluate individualized predictive models integrating clinical, behavioral, and biologic determinants rather than relying on aggregated community measures.

Background

In the United States, the perioperative period has been shown to be a frequent and important entry point for transitioning opioid-naïve patients into the persistent crisis of opioid dependency and addiction.[1,2] Opioid reduction laws have passed in several states in an attempt to mitigate this crisis; however, because physicians have historically used the "one-size-fits-all" model for prescribing postoperative acute pain management, these changes have proven ineffective in stemming the rising rates of overdose deaths.[1,2]

Persistent postoperative opioid use (PPOU) serves as a metric for determining the prevalence of long-term opioid usage among patients who were opioid-naïve prior to surgery. While the definition of PPOU may vary[3], research to date indicates it occurs in approximately 7–10% of opioid-naïve patients postoperatively.[2,4] PPOU continues to amplify the ongoing opioid crisis that has impacted communities across the United States and has contributed to over 1 million deaths since 1999[5]. The Appalachian region is known to have unique socioeconomic and healthcare disparities and stands out as one of the areas in the USA that is most profoundly affected by opiate crisis.[6]

Social determinants of health (SDoH) encompass a range of factors beyond traditional medical variables, including socioeconomic status, education level, access to healthcare, and community resources that impact patient outcomes. Multiple indices have been created to assess community-level vulnerabilities [5–11]. In addition, different approaches have been developed to improve the ability of these measures to associate health disparities with medical outcomes, resulting in continuing refinements to these public health tools. The Agency for Toxic Substances and Disease Registry (ATSDR) of the Centers for Disease Control and Prevention (CDC) introduced the Social Vulnerability Index (SVI) to assess the vulnerability of communities that may need support before, during, or after disasters. Several studies have used the SVI to examine patient outcomes.[7–10] Other indices have also been introduced, such as the Vizient Vulnerability Index (VVI), developed by Vizient, Inc., which adapts the weighting of multiple domains based on their local relevance and correlation with life expectancy.[11,12] The Distressed Communities Index (DCI), developed by the Economic Innovation Group, utilizes the American Community Survey (ACS) to calculate a multiyear average ACS score for each zip code[13]. Similarly, the now-discontinued Community Needs Index (CNI) developed by Dignity Health and Truven Health Analytics, created an index based on five socioeconomic indicators.[14, 15] These indices highlight social barriers caused by environmental and social factors within the biopsychosocial model[16], an approach assessing the overall health of individuals.

This study has sought to determine whether community-level indices can help identify the risk of developing PPOU among opioid-naïve patients undergoing surgery, with the goal of informing strategies to reduce this risk.[16] Therefore, in this study, we used four validated tools to examine whether community-level scores of our Appalachian Region patient population in East Tennessee are associated with an increased risk of PPOU. By evaluating how SVI, VVI, DCI, or CNI relate to PPOU, we aimed to identify underlying factors driving opioid dependence in previously opioid-naïve surgical patients and evaluate any potential correlation with at-risk patients.

Methods

Study design and patient population

This retrospective, observational study examined the association between SVI, VVI, DCI, and CNI scores and PPOU among 913 consecutive patients who underwent nephrectomy, mastectomy, or colectomy for any cause at the University of Tennessee Medical Center (UTMC), Knoxville, TN between January 2018 and March 2022. All patients were aged 18 years old or older and had not received any opioids within 30 days prior to surgery, which we defined patients as being opioid-naïve. Demographic and clinical data, including patient characteristics, address information, social history, number of complications, surgery type, length of hospital stay, number of analgesics used, and post-operative opioid consumption at 30, 60, and 90 days, were retrospectively extracted from the UTMC's electronic medical records (EMR) and the State of Tennessee Controlled Substance Monitoring Database, which is directly integrated with our hospital's EMR system. In addition, covariates, such as mental health history, smoking status, alcohol consumption, and body mass index were obtained through patient chart review.

Definition of PPOU Our definition for a patient having PPOU is whether they had an opiate prescription given to them to treat post-surgical pain at discharge and at least one additional opioid prescription filled 60 to 90 days post-surgery.[3]

Social Vulnerability Index (SVI): The patient address data extracted from the EMR were utilized to ascertain the SVI scores at both the county and census tract levels using the CDC/ATSDR 2020 interactive map and tables. These SVI scores defined by the CDC are based on 16 distinct social factors, which are further categorized into four vulnerability themes, utilizing the American Community Survey (ACS) 2016–2020 (5-year) data for: socioeconomic status, household characteristics, racial and ethnic minority status, housing type, and transportation (Fig. 1). The SVI census tract and county percentile ranking values span from 0.0080 (indicating very low-level social vulnerability) to 1.000 (indicating extreme level social vulnerability). These rankings were aggregated for each theme, to derive a theme-specific ranking.[18] The continuous SVI rankings were also classified into 4 vulnerability level categories: low (< 0.2500), low-to-medium (0.2500 -0.4999), medium-to-high (0.5000-0.7499), and high (≥ 0.7500).

Vizient Vulnerability Index (VVI)

The Vizient Vulnerability Index file launched in 2021 provides users with data to address 43 different social drivers of health at the neighborhood level. This file includes nine domains of social needs, as well as the overall vulnerability index for each census tract and ZIP code throughout the United States (Fig. 2). Using this index, a score greater than 1.0 indicates a "High Vulnerability" area, meaning these neighborhoods face challenges to accessing care that are more than one standard deviation above the national average. The index combines data from the ACS 2016–2020 5-year estimates and the USDA's "food desert" metric to identify low-income populations in rural and urban areas. It also incorporates Housing and Urban Development's "severe housing cost" measure to track households' spending along with many other data including provider shortages and opioid dispensing rates data.[14]

Distressed Community Index (DCI): The DCI developed by Economic Innovation Group (EIG) in 2015, highlights the significant economic disparities that exist among U.S. communities. Utilizing the most recent census data (2017–2021), using ACS 5-year estimates, zip codes, counties, and congressional districts are categorized into five tiers of economic well-being: prosperous, comfortable, mid-tier, at risk, and distressed. This

stratification enables a detailed examination of disparities both within and between cities and states. The index evaluates these differences based on seven key components. These components are no high school diploma, housing vacancy rate adults not working, poverty rate, median income ratio, changes in employment, percent change in the number of jobs over the past five years[13] (Fig. 3**).** In this tool, zip codes are ranked across seven metrics, averaged, and normalized into a Distress Score from 0 to 100 (most prosperous to most distressed). Based on these scores, communities are categorized into five tiers: prosperous, comfortable, mid-tier, at risk, and distressed. The same approach is used for counties and congressional districts.

The Community Needs Index (CNI): The CNI is a tool developed by Dignity Health and Truven Health Analytics in 2005. It aggregates five socioeconomic indicators long known to contribute to health disparity–income, culture/language, education, housing status, and insurance coverage–and applies them to every zip code in the United States. Each zip code is then given a score ranging from 1.0 (low need) to 5.0 (high need)[14, 15].

Statistical Analysis

The dependent variable was new PPOU; refill 60–90 days after discharge. Exposures of interest were community-level indices (SVI, VVI, DCI, CNI); covariates included age, sex, BMI, smoking, alcohol use, psychiatric history, surgery type, extent of resection (total/radical vs partial), and length of stay (LOS). We summarized categorical variables as counts (%) and continuous variables as mean (SD) or median (IQR) as appropriate. Univariate comparisons used χ^2 or Fisher's exact tests (categorical) and t-tests or Mann–Whitney U tests (continuous). We estimated odds ratios (ORs) with 95% confidence intervals (CIs) using logistic regression. We report univariate ORs and a prespecified multivariable model adjusted for age, sex, BMI, smoking, alcohol, psychiatric history, surgery type, extent of resection, and LOS. Model selection followed clinical relevance (Fig. 5). As secondary analyses, we evaluated readmission within 0–30, 30–60, and 60–90 days and any readmission within 90 days for association with PPOU. Two-sided $\alpha = 0.05$.

Results

Of the 913 patient records examined, 371 had nephrectomy, 194 had colectomy, and 348 had partial or radical mastectomy. 95.8% of the population were Caucasian, 2.9% were African American and 1.3% were other races which is reflective of the East Tennessee Appalachian population. 65% of the patients were female. This was expected as mastectomy procedures for breast cancer is more common in women than in men. Overall, the median patient age was 64 years (IQR 53 to 73 years). 63.5% of patients were married or living with a partner, while the rest were single, never married, widowed, or divorced.

PPOU occurred in **8.6% (73/913)** of patients. Compared with patients without PPOU, those with PPOU had **longer LOS** ($p=0.040$) and were more likely to have **total/radical resection** vs partial (univariate OR ≈2.5–2.7; see Table 2). Community-level indices (SVI, VVI, DCI, CNI) were **not associated** with PPOU in univariate tests or multivariable models (Table 2). In secondary analyses, **readmission** was associated with PPOU at **30–60 days** and **60–90 days**, and for **any readmission within 90 days** (all $p<0.001$)

Table 1: Patient Characteristics and Perioperative Factors Associated with Persistent Postoperative Opioid Use

	Patients with PPOU	Patients with No PPOU	p-value
Age at surgery, mean (SD)	61.2 (13.4)	62.1 (14.0)	0.438
BMI, mean (SD)	29.8 (7.3)	29.4 (6.8)	0.76
Female (%)	69.9	64.5	0.43
Caucasian Race (%)	91.8	96.2	0.193
Hispanic/Latino (%)	1.4	0.5	0.868
Currently Employed (%)	41.1	36.0	0.17
Insurance: Public (%)	60.3	58.9	0.944
Insurance: Private (%)	39.7	40.6	0.944
Insurance: Uninsured (%)	0.0	0.4	0.944
History of Anxiety (%)	21.9	24.4	0.739
History of Depression (%)	32.9	26.5	0.303
Any Psychiatric Illness (%)	43.8	38.2	0.412
Benzodiazepine Use (%)	6.8	12.6	0.208
Alcohol Use (%)	6.8	7.7	0.965
Tobacco Use (%)	16.4	16.5	1.000
Perioperative Nerve Block Performed (%)	49.3	50.1	0.992
Length of Stay (Days), mean (SD)	2.7 (2.8)	2.1 (2.1)	0.040*
Surgery: Total Resection	57.5	33.6	<0.001*
Surgery Type:	46.6	40.1	0.308
-Nephrectomy	37	38.2	
-Breast Surgery	16.4	21.7	
-Colon Surgery			
Readmission < 90 Days	38.4	16.4	<0.001*

*p<0.05

Table 2: Comparison of SVI, DCI, CNI, and VVI Scores, And Length of Hospital Stay in Patients Undergoing Nephrectomy, Mastectomy, or Colectomy At UTMC, with and without PPOU Outcomes

	Patients with PPOU n=73	Patients with No PPOU n=840	*p*-value*
Total or partial organ/ tissue removal (n%)			<0.001*
Total or radical	42 (57.5%)	282 (33.6%)	
Partial	31 (42.5%)	558 (66.4%)	
Length of Hospital Stay [IQR]	1.50 (2.10)	1.30 (1.40)	0.040*
SVI (state level, census tract units [SD])[b]	0.42 (0.25)	0.43(0.26)	0.818
VVI (zip code [SD])[b]	1.14 (0.81)	1.11 (0.86)	0.429
DCI (zip code[SD])[b]	58.51(37.8)	54.88(40.3)	0.845
CNI (zip code [IQR])[b]	3.40 (0.8)	3.40 (1.0)	0.238

*p<0.05 *Frequency distributions and percentages were calculated for the total and radical organ/tissue removals. Means and standard deviations [SD] were used for the continuous normally distributed data. Medians and IQR were reported for the continuous non-normally distributed data.*

[a]*PPOU: Persistent perioperative opioid use.*

[b]*SVI, VVI, DCI, or CNI scores are the overall ranking related to the social vulnerability*

** Non-normally distributed data were assessed for statistical* significance *using the non-parametric Mann-Whitney U-test, while parametric independent t-tests were employed for normally distributed data. The statistical significance was assumed at an alpha level of 0.05.*

The univariate analysis demonstrated a significant association between development of PPOU and longer hospital stays (*p*=0.040, [OR]: 1.11, 95% [CI]: 1.02 – 1.21) (Table 2). We also found that there is a significant association between PPOU and the amount of tissue removed during the surgery (*p*<0.001). Patients undergoing total or radical nephrectomies, mastectomies, or colectomies exhibited higher odds of having PPOU (odds ratio [OR]: 2.68, 95%CI [1.65 – 4.36]) when compared to those undergoing partial resections.

In our analyses, however, patients' BMI, age, sex, smoking status, alcohol use and community-level vulnerability scores determined by the four different community indices-SVI, VVI, DCI or CNI- did not demonstrate any significant association with PPOU**.** Moreover, developing PPOU was not associated with other variables such as surgery type, anxiety, depression, other mood disorders which are commonly cited as risk factors associated with chronic opioid use[19] (p>0.05).

In multivariate logistic regression models (Figure 5) adjusted for demographic, surgical, and psychosocial covariates, none of the social vulnerability indices were independently associated with PPOU. The CNI demonstrated a non-significant trend toward increased risk (AOR, 1.29, 95% CI 0.91-1.84, p=0.15), while the

VVI, DCI, and SVI showed no association (AORs 1.16, 1.00, and 1.01, respectively, all P>0.3). Across all models, 90-day readmissions and total resections remained strongly associated PPOU (AOR ~7 and 2.6, respectively, p<0.001). In all models, LOS showed a consistent but nonsignificant positive association with PPOU (AOR ~1.09, p=0.1).

Discussion

The ongoing regional opioid crisis in Appalachia remains a critical public health concern with a reported 37% higher drug overdose rate than the rest of the United States.[20] To mitigate the risk of long-term opioid dependence from prescriptions among patient populations, it is essential to understand the relationship between social drivers of health and the type of medical interventions that include post-operative pain control for acute pain management using opioid medications. Understanding the nuanced relationship between patient demographics, social determinants of health, surgical procedures, and postoperative opioid use patterns must be developed when making plans for perioperative pain control. Our study found an 8.6% incidence of PPOU, aligning with previous reports of 7–10% among post-surgical hospital patients after discharge[4, 21] The incidence of PPOU in our study highlights a significant health concern, considering the high volume of surgical procedures performed each year in the United States, potentially leading to a substantial number of new opioid-dependent individuals.

In this Appalachian cohort, community level indices (SVI, VVI, DCI, CNI) did not show individual-level associations with PPOU after adjustment, whereas the extent of surgical resection and 90-day readmissions were associated with PPOU. This pattern suggests that ecological measures may have limited utility for patient-level risk in perioperative settings, consistent with concerns about ecological fallacy with applying aggregate metrics to individual outcomes. In Fig. 6, we compared some of the limitations of these four community level vulnerability indices. Considering these limitations and our findings, future research could benefit from employing more granular public health tools tailored to specific patient cohorts to better capture the nuanced dynamics. Particularly, for PPOU, personalized medicine offers the potential to provide more precise measures of social vulnerability, especially in conjunction with pharmacogenomic testing of drug metabolism and pain receptor pathways, moving away from a “one size fits all approach” to treatment of post-operative acute pain management.

A prior study by Amaro et. al has identified preoperative use of tobacco, alcohol and substance abuse disorders, mood disorders, anxiety, and preoperative pain disorders as being independently associated with PPOU and many of these independent risk factors cluster within communities with high social vulnerability [22]. Our study sought to evaluate the relationship between community-level social vulnerabilities assessed using 4 different indices, SVI, VVI, DCI and CNI, and patients who develop PPOU. All of these public health tools are derived from different variables associated with census tracts at the state level (SVI) or zip codes (VVI, DCI or CNI) and contain community-level data. The fact that none of these measures of social vulnerability were associated with PPOU could be due to an ecological fallacy that can occur due to use of group level or aggregate-level data while trying to explore potential associations between variables. To determine if this is the case, a prospective study examining the relationship between exclusive community level data and community-level incidence of PPOU comparing two separate regions would be required. This will allow

researchers to determine if our finding of non-association is caused by an ecological fallacy and will guide future developments of public health tools to allow individual outcome predictions [23].

While these community level indices did not show association, we did find postoperative clinical and procedural variables that were more strongly associated with PPOU. Specifically, 90-day hospital readmission emerged as a consistent and significant association with PPOU across all models, conferring more than a sevenfold increase in odds of ongoing opioid use after surgery. This finding may reflect the combined influences of postoperative complications, prolonged recovery, and repeated exposure to opioids during additional medical encounters. In addition, more invasive surgical resection, as opposed to partial resection, was associated with higher odds of PPOU. This may underscore the impact of surgical magnitude on tissue trauma and postoperative pain trajectories and analgesic requirements.

It is essential to acknowledge the limitations of our study, including those inherent to retrospective design and reliance on patient-reported data from electronic health records, which may introduce biases or result in incomplete information. Firstly, this study focused on 3 surgical subtypes to ensure consistency in pain management pathways and minimize procedural heterogeneity. Although this approach enhances internal validity, it limits the generalizability of findings to other surgical populations. However, prior work by Brummett et al[21] demonstrates comparable rates of in PPOU rates across broad ranges of surgeries, suggesting that the relationships observed here may extend beyond the included surgical types.

Secondly, our study population predominantly represented a rural Appalachian demographic with limited racial and ethnic diversity. While this provides valuable insight into a frequently underrepresented population at risk of elevated opioid-related morbidity, it, may limit the generalizability of our findings to other populations. Additional racial and ethnic minority groups may experience differing patterns of pain perception, opioid prescribing, and postoperative follow-up access. These risk factors could not be adequately assessed in our data set and would recommend additional research in more heterogenous populations.

Finally, the lack of a clear, concise definition of PPOU in all studies is also potentially problematic for quantifying an accurate incidence of opioid-naïve individuals who develop opioid dependence. Despite this, the incidence of PPOU in our study remains within the expected range found within the established literature.

To effectively combat the opioid epidemic, a multifaceted approach is essential. This should involve implementing and enhancing evidence-based interventions at the individual, community, and policy levels to promote safer opioid prescribing practices and expand anesthesiology-directed pre- and post-operative support services specialized in managing both acute and chronic pain. Collaboration between regional healthcare providers, policymakers, and community stakeholders is crucial in developing comprehensive strategies that address the underlying social and genetic determinants contributing to PPOU, ultimately leading to better outcomes for patients undergoing surgical procedures.

Conclusion

Our study contributes to the growing body of literature on PPOU by examining the influence of community-based social vulnerability factors on opioid use patterns among surgical patients in East Tennessee. Although

the community-level indices are useful to be part of a broader approach to understand and address patient vulnerabilities, they cannot be used as standalone tools. Our study showed that community-level social vulnerability indices were not associated with individual postoperative opioid dependence in previously opioid-naive patients. Thus, new indices, especially in homogenous or isolated communities, using genomic studies, pharmacogenomics or finding a way to individualize community social determinants of health for individual patients to elucidate the complex interplay between demographic characteristics, social determinants, and opioid-related outcomes. We hope that by doing this it will be possible to inform targeted interventions that reduce the burden of prescription induced opioid misuse and improve the quality of care for vulnerable patient populations.

Declarations

- **Ethics approval and consent to participate**

All research carried out adhered to the guidelines for human research in the Declaration of Helsinki. This study was approved by the University of Tennessee, Graduate School of Medicine IRB and the need to obtain individual consent was waived.

- **Consent for publication**

Not Applicable

- **Availability of data and materials**

Deidentified data are available from the corresponding author on reasonable request

- **Competing interests**

All authors have no competing interests to declare

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Authors' contributions conceived the project (CP), collected the data (CD) conducted the statistical analysis of the data (CS), wrote the paper (WP). All authors confirm that they have reviewed the final manuscript and approve submission. Trey Henderson (CD, CS WP), Gulsah Onar (CD, CS), Aimee Pehrson (CP), Paul D. Allen* (WP), Jason Buehler (CP, CD, WP).

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Figures

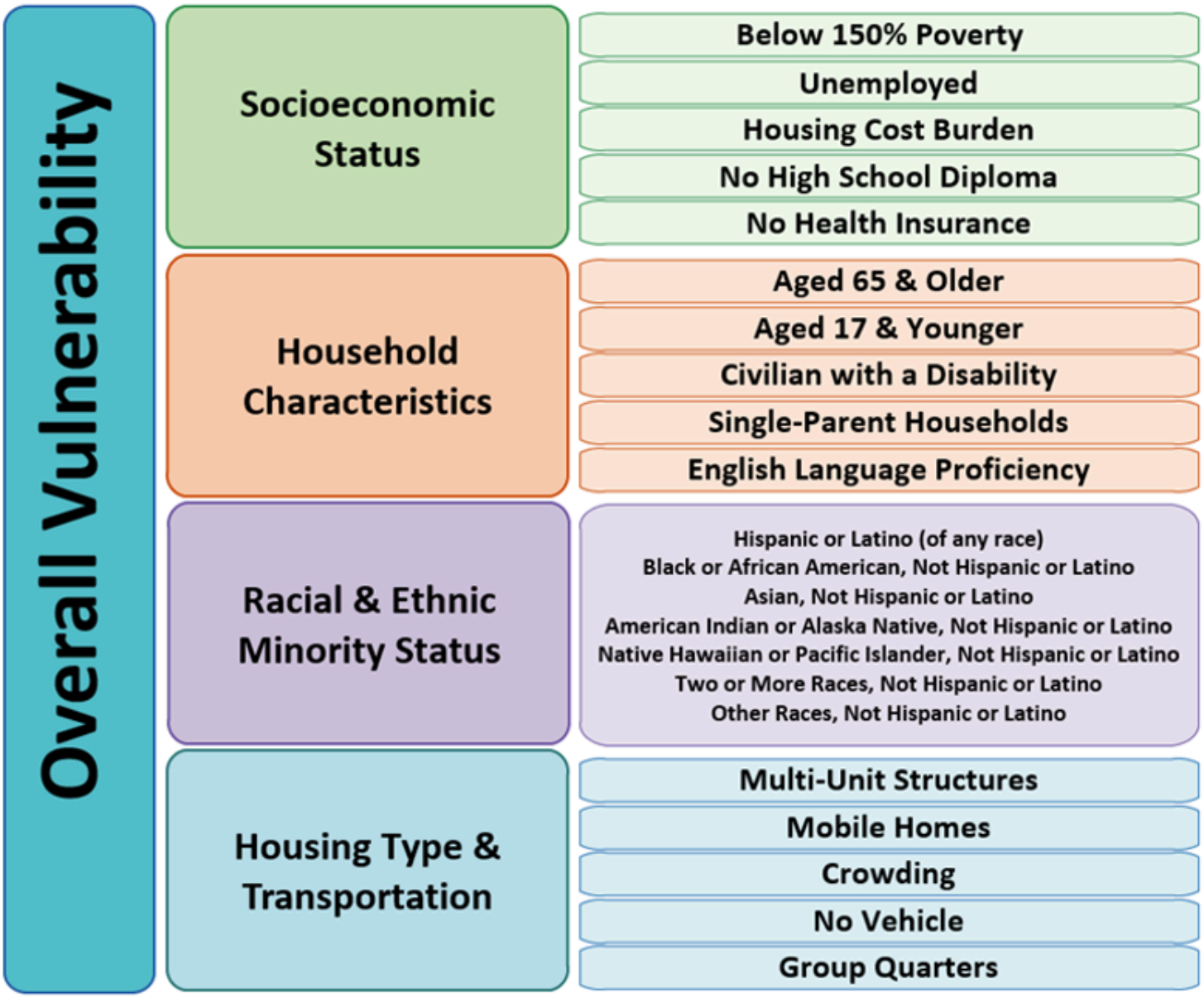


Figure 1

Vulnerability themes and variables by CDC/ATSDR that were used for the Social Vulnerability Index (SVI) devised by Flanagan et. al.[17]

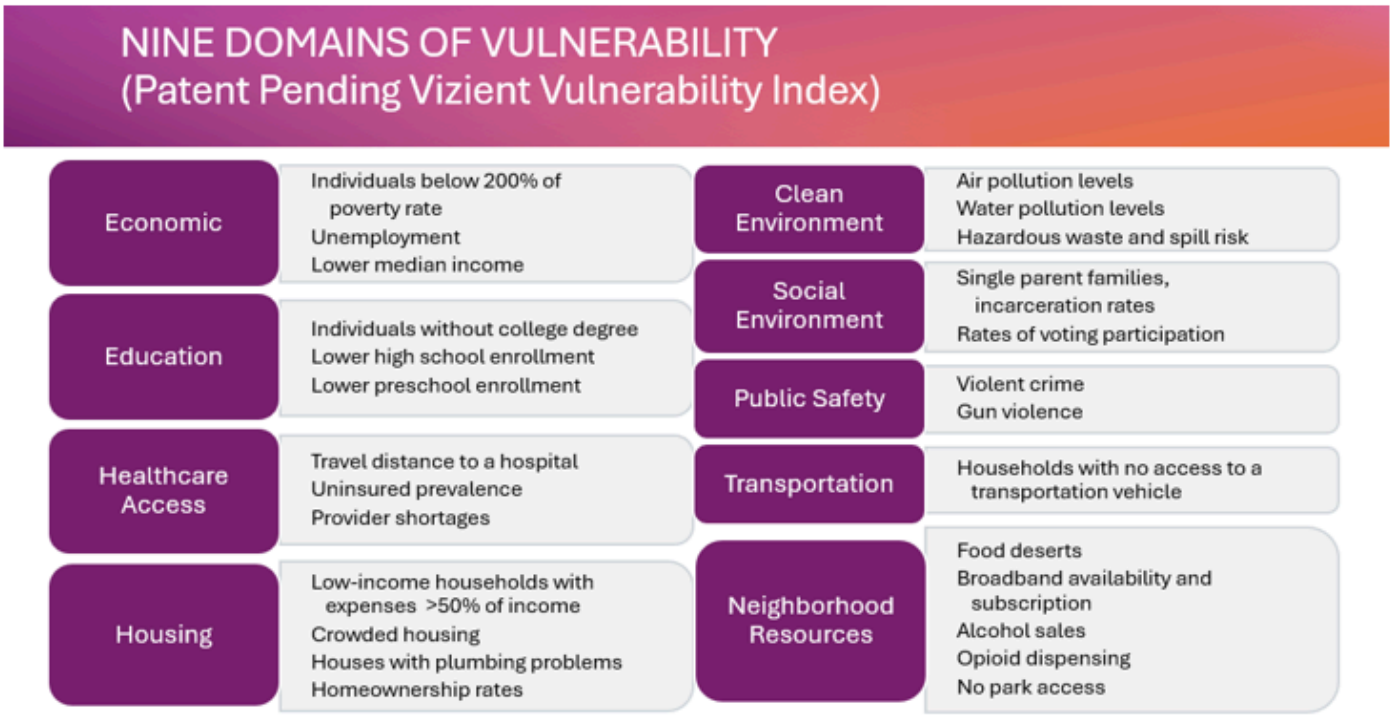


Figure 2

Vizient Vulnerability Index (VVI): Domains of Vulnerability

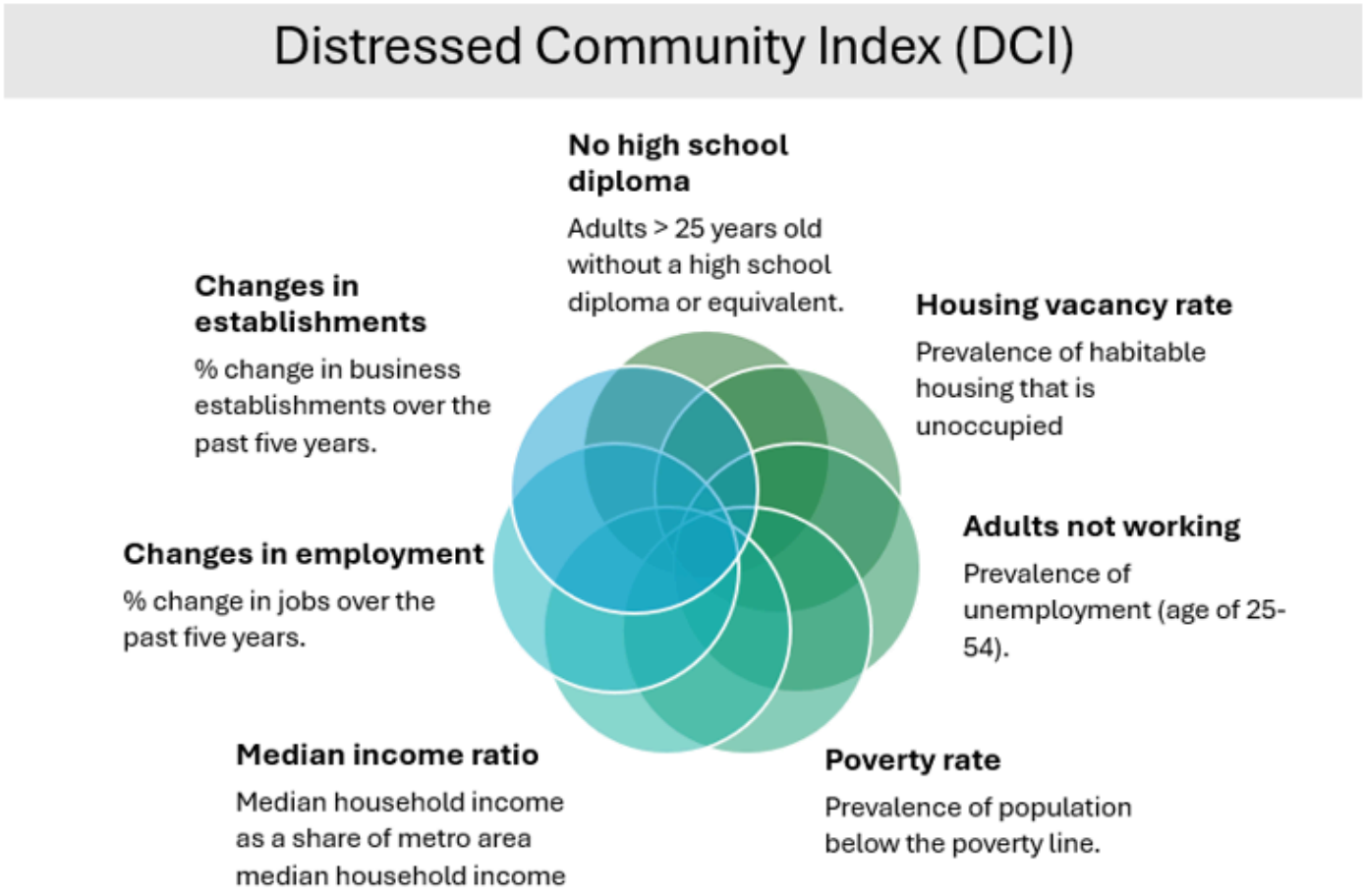


Figure 3

Distressed Community Index by EIG using 2017-2021 ACS 5-year estimate U.S. Census data

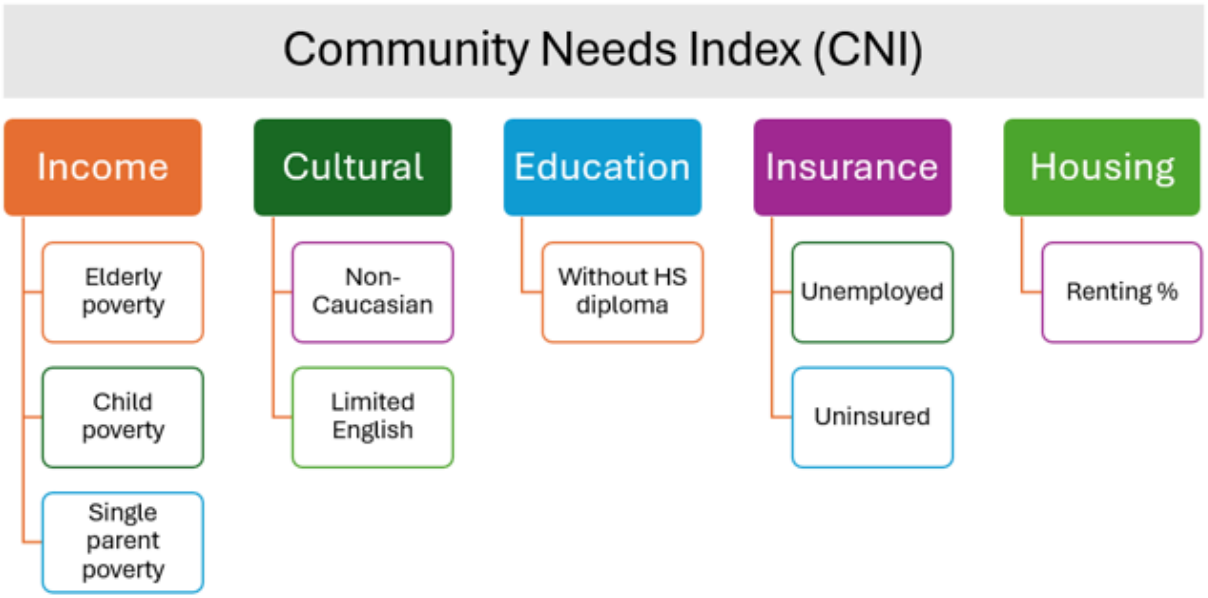


Figure 4

Community Needs Index (CNI) tool developed by Dignity Health (2005)

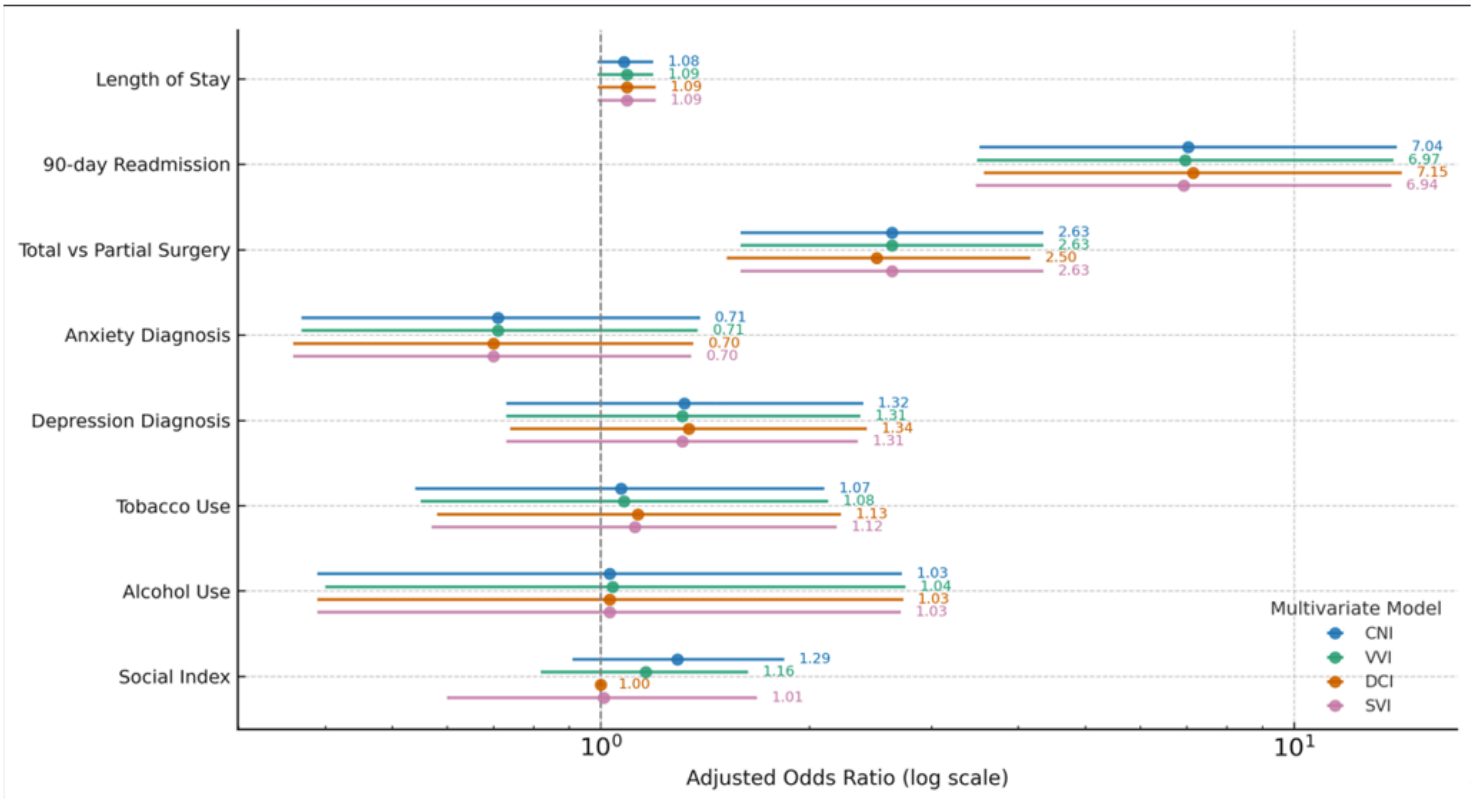


Figure 5

Multivariate Logistic Regression Models for Social Vulnerability Indices and Persistent Postoperative Opioid use